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TRANSACTIONS OF THE DETROIT OBSERVATORY
UNIVERSITY OF MICHIGAN.

PART I.

DETERMINATION OF THE ABERRATION CONSTANT FROM ZENITH DISTANCES OF POLARIS, MEASURED WITH THE WALKER MERIDIAN CIRCLE

BY

ASAPH HALL, JR.

DIRECTOR OF THE OBSERVATORY.

PRESENTED AT THE EIGHTH ANNUAL MEETING OF THE MICHIGAN ACADEMY OF SCIENCE, MARCH 27, 1902.

REPRINTED FROM THE FOURTH REPORT OF THE MICHIGAN ACADEMY OF SCIENCE.
1904.

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The Observatory.

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I.—Introduction.

The Detroit Observatory of the University of Michigan was built about 1854 through the efforts of President Tappan, money for the purpose being raised in Detroit. Mr. Henry N. Walker of Detroit was especially interested in the project and gave funds for the purchase of the meridian circle.

The observatory building is of the usual old-fashioned type, a central part, on the top of which is the dome for the equatorial, and east and west wings, the meridian circle being in the east wing and the library in the west. All the walls are of heavy masonry, so that the temperature in the observing rooms changes slowly.

In addition to the Walker meridian circle the observatory was equipped at first with a 12¾-inch equatorial constructed by Fitz, and a clock by Tiede of Berlin. The equatorial has the old German style of mounting with a wooden tube. As far as I can find out the driving clock was never of any use. Also, it is rather difficult to manage the illumination of the micrometer, so that with it few systematic observations were made. The object glass is a fair one. With this instrument Professor Watson discovered twenty-one asteroids. A number of these were observed but a few times and are now lost. The difficulty in using the micrometer is probably the reason for the small number of observations of them made at Ann Arbor.

Observations of comets and asteroids were also made with this instrument by Dr. Brünnow, Professor Watson and Messrs. Schaeberle, Campbell, Hussey, and Townley. I believe that several comets were discovered with it.

The Tiede Clock has now an irregular rate.

About 1880 a small observatory was erected near the large building, designed especially for practice work. In it were placed a 6-inch equatorial with a Clark glass, and mounting by Fauth, and a 3-inch Fauth meridian transit.

The object glass of the equatorial is good, with the sharp definition characteristic of the Clark glasses. The mounting is fair, though the driving clock, having a Foucault governor, is too weak.

With this equatorial observations of comets and asteroids have been made by Messrs. Schaeberle, Campbell, Hussey, and Townley.

The object glass of the meridian transit is poor. λUrsae Minoris cannot be seen with a bright field. The pivots rest on wide and flat agate bearings, an arrangement which is wrong mechanically, and may account for the existence of two azimuths.

The observations made at Ann Arbor have been published in the various astronomical journals and in the American Journal of Science. In the way of records there is very little.

The observatory building is on a hill south of the Huron River, on clay

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soil. Along the river runs the Michigan Central Railroad and the passing of the trains sometimes makes it difficult to determine nadirs. The prevailing winds are westerly. The best seeing is usually in the spring and summer, though there is fine weather also in October, December, and January. There is considerable dampness.

The instruments of this observatory were in bad condition when they came into my hands. It was necessary to take apart and clean the object glasses. Tackles were rigged in the slits of the domes, and the tubes, axes, and bearings of the axes were taken down, and the accumulations of oil and grease removed.

2.—Latitude and Longitude of the Detroit Observatory.

As to the latitude no record of an accurate determination can be found. From the discussion which follows of observations of Polaris the latitude can for the present be assumed

+42° 16′ 48.8″.

The value +42° 16′ 48.0″ as printed in the ephemerides was, I think, an approximate determination, +42° 16′ 48″, the .0 being finally added by accident.

The best determination of longitude is probably that found by connecting with Hamilton College, Clinton, New York. Dr. Brünnow observed at Ann Arbor and Dr. Peters at Clinton. The difference of longitude was found to be

33m 17.69s.

Hamilton College had been previously determined with respect to Cambridge, and was found to be west of Cambridge

17m 6.48s.

Thus the Detroit Observatory is west of Cambridge

50m 24.21s.

See Brünnow's *Astronomical Notices,* numbers *15* and *27*.

Also, Ann Arbor was twice connected with Detroit, and Detroit was connected directly with Cambridge. See pp. 716, 717, 869 of *Professional Papers, Corps of Engineers, U. S. A., No. 24,* also the *Spherical Astronomy* of Brünnow, one of the examples under the Method of Least Squares. From these determinations Detroit is west of Cambridge.

47m 41.17s.

and Ann Arbor is west of Detroit

2m 43.10s.

In the second exchange of longitude signals between Ann Arbor and Detroit apparently there was no telegraph line running to this observatory. The signals from Ann Arbor seem to have been sent from a chronometer which was carried to the telegraph office.

3.—The Walker Meridian Circle.

An investigation of the division errors of the fine circle of this instrument was published in Brünnow's Astronomical Notices. I cannot find that anything else has been printed regarding it.

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In the Notices are given, also, the determinations of the places of a number of comparison stars for asteroids and comets. Several of the older graduates have told me that Brünnow made with this meridian circle an elaborate series of observations of the Bradley stars, the records of which he took to Europe for reduction, by permission of the University authorities. I cannot find out anything regarding such observations.

Professor Watson, after taking charge of the observatory, seems to have been interested in the construction of ecliptic charts and the discovery of minor planets, and not to have made any regular use of the meridian circle. It was employed by Professor Schaeberle, however, for the observation of latitude stars, Struve double stars, and planets. See report of Professor Harrington to the Regents, 1881. A list of 155 stars observed by Professor Schaeberle was printed in the "Publications of the Washburn Observatory." They were reduced, it is stated, differentially, but none of the constants of reduction are given.

After some experience at the Naval Observatory under Professor Eastman, I became interested in meridian circle work, and on coming to this place resolved to make such observations. A new micrometer was purchased from the Repsolds, a chronograph from Saegmüller, and a clock from Howard. The object glass was taken to the Clarks' shop and a spring was put in the cell to act against the glass. The instrument was taken to pieces and carefully cleaned. Observations were begun of a list of Bradley stars, including a number to be used for latitude at the Georgetown College Observatory.

On looking up the latitude of this place no record could be found of an accurate determination, so that observations were made of Polaris, both for the purpose of determining latitude and with the idea of obtaining the amount of latitude variation at Ann Arbor. Also, an examination was begun of the division errors of the fine circle, to test the permanency of the values given by Dr. Brünnow. The reduction of the nadirs was kept up, and they seemed to show that the instrument was steady and the work good. During term time of the University it was necessary to neglect the other reductions. As soon as they could be brought up the work was shown to be not first rate. The reduction of the observations of the Bradley stars are pretty well completed. They can be used, I think, if they are made strictly differential.

On looking the instrument over again the following trouble was found which had probably existed since it was first mounted. To support our meridian circle two brass cones with lugs attached are let into the stone piers, and to the cones are screwed heavy brass discs. The discs support the wye blocks which carry the pivots, and to the discs, also, are clamped the microscope arms. The cones were found to be loose in their packing. This packing was what seemed to be mortar mixed with brick dust, the brick dust being added, I suppose, to make the mixture hydraulic. See the older hand books of engineering under cements. The packing when removed was a fine, dry dust.

I attempted to mount the cones in the piers first with lead and then with plaster of Paris. Finally Portland cement was used and with it they seem steady. We are under obligations to Mr. Fecker, superintendent of Warner and Swasey's instrument department, and to Messrs, Warner and Swasey for the remounting of the instrument. Mr. Fecker called my attention to the fact that the object glass cell fitted loosely in

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the telescope tube, so that its weight came entirely on the three collimating screws. A new cell was made, therefore, with a bell flange, fitting tightly in the tube and having a better spring to work against the object glass. I have wondered whether the curious flexures shown by some meridian circles might not be produced in this way, by the bending of the collinating screws on account of the object glass cell resting on them.

After the instrument was remounted it was necessary to take up some work that should test it. Also, the reductions could not be too heavy, for it would not do to allow them to fall behind. Finally it was decided to begin again observations of zenith distances of Polaris with the idea of determining the aberration constant, since a number of the values found according to the method of Küstner differed considerably.

4.—Description of Meridian Circle.

This instrument was constructed by Pistor and Martins in 1854. It is of brass with steel pivots. It is unsymmetrical with respect to the cube, the cone carrying the object glass being 4 feet 1½ inches long, while the length of the eye end cone is 3 feet and ¾ inches. The total focal length is approximately 8 feet 3¼ inches. A lead ring is placed inside the tube, near the micrometer, to balance the greater weight of the object glass end. The length of the axis is 3 feet 5¾ inches. The diameter of the objective is 6.3 inches. The object glass and eye ends of the telescope cannot be interchanged.

The instrument is mounted between sandstone piers as described in Art. 3. The piers are not covered with wood or felt. The substructure is brick.

The dimensions of the observing room are, north and south, 26 feet 3 inches; east and west, 17 feet 8½ inches; height, 13 feet 3½ inches; width of opening, 2 feet 6¾ inches. The room is too small. There is hardly sufficient space for reflected observations, and there is no proper arrangement for ventilation so that the temperature inside shall follow quickly the changes of the outside air. Moreover, being built on as a wing to the main building, the heating and cooling of this might produce refractions different from those of the tables.

5.—The Object Glass.

This is rather poor, containing tree-like formations. The rays of light are not brought sharply to one focus. Still the images are pretty fair, and round all the way across the field.

6.—The Micrometer.

The micrometer has a right ascension screw, with the Repsold device for automatic registration of transits. The value of one revolution is approximately 3.640s. There is no zenith distance screw, and I may have made a mistake in not having it. But I had become suspicious of some of the complicated arrangements at the eye-ends of the large meridian circles, and determined to make the zenith distance pointings with the tangent screw of the telescope.

With this micrometer can be used only a bright field. The light is thrown down the axis of the instrument, and reflected by a large mirror in the cube, the mirror being pierced in the center by a circular opening in order to let through the cone of rays from the object glass. The amount

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of light falling on the mirror is regulated by opening or closing slats placed in the axis of the telescope.

As the Repsolds had only the old Pistor and Martins micrometer to work from they declined to attempt any arrangement for lighting the wires, for fear, I suppose, of producing an unsymmetrical illumination.

For all observations the same eye-piece has been used, magnifying 160 times. This is about as high a power as it is possible to employ over the nadir basin. A number of attempts were made to use higher powers, but the nadir could not be obtained with them except when the air was quite steady.

7.—*The Pivots.*

The pivots are approximately 1.819 inches in diameter. They must have been very carefully made. Professor Schaeberle cleaned them, I understand, with graphite and oil before beginning work with this instrument. They were polished afterwards, also, by Professor Asaph Hall, in 1894, with fine pumice stone and watch oil. The rust which had formed on them had made etchings apparently, but had not injured their form. I think they are as round now as when they were made.

It was not possible to test the pivot inequalities with the hanging level, since the wye blocks are so large that the level wyes cannot be placed over the bearings of the pivots. To examine the pivots, therefore, I had the observatory purchase from Saegmüller a spherometer caliper. A description of this is given in Doolittle's Practical Astronomy. Though exceedingly delicate measures can be made with it the results are not very definite, as it is now constructed, for the upper and lower bearings are not in the same vertical plane. It merely shows in a general way whether or not the pivots are good.

Before taking the measures the two telescope ends and the circles were removed from the cube, and it was placed on a wooden support like that of the reversing carriage. Settings of the caliper were made on those parts of the pivots on which the wyes bear, and on which the level wyes are usually placed. Eight positions of the cube were taken: eye-end up and down; edge of cube near 1854 in vertical, up and down; side inscribed *Berlin,* horizontal, two positions; edge near Pistor and Martins, in vertical, up and down. These positions were 90° apart.

Twenty settings of the caliper were made in each position. From ½ inch and ¼ inch steel blocks furnished by Brown and Sharp, one revolution of the spherometer screw was found to be

0.00974754 in.

From the settings on the pivots we have the following results:

BEARINGS ON Y'S.

	Fine circle end.	Coarse circle end.
Eye-end	0.3823r	0.3718r
Edge 1854	0.3938	0.3818
Side Berlin	0.4214	0.3847
Edge Pistor and Martins	0.4298	0.4231
Means	0.4068r	0.3904r

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Thus we find a shape slightly elliptical. One half the difference of the means is 0.0082r, or 0.000082 in. Since the length of the axis of the meridian circle is 41¾ inches, this would produce an inequality of 0.4051″ or 0.0270s, the coarse circle end being the bigger.

BEARINGS OF LEVEL.

	Fine circle end.	Coarse circle end.
Eye-end	0.3706r	0.3658r
Edge 1854	0.3698	0.3524
Side Berlin	0.3698	0.3714
Edge Pistor and Martins	0.3625	0.3634
Means	0.3682r	0.3632r

One half the difference of the means is in this case 0.0025r, or 0.000025 in., producing an inequality of 0.1235″ or 0.0082s.

The weight on each pivot is approximately 34 lbs.

8.—*The Circles.*

There are two circles, one divided to 2′ and one to 10′. Each is read by four microscopes to 0.1″. Both circles were cleaned by me with fine whiting in 1893. Evidently both had been cleaned a number of times before, but the lines on the coarse circle are in better condition than those on the fine circle. On the fine circle they are faint in several places. As originally cut the lines must have been rather fine and delicate. The more modern method of making them heavy is better, and the heavy marks can be pointed on just as accurately, as far as I can see.

The circles are approximately 37½ inches in diameter. Each is supported by ten ribs running from the central hub. The ribs and the circles themselves are rather light, so that there is some distortion by gravity. The ribs are numbered I, II, ... through X. The fine circle is not figured. I have considered the degree mark opposite X to be 0°, that opposite I to be 36°, and so on. Opposite 72° I placed a scratch on the silver band. Afterwards it was found that a cross had been placed opposite 314°, which perhaps had been used on Polaris.

The fine circle was investigated by Dr. Brünnow to every fifth degree. These results are reprinted here from the Astronomical Notices, both to show the character of the circle, and for possible use with any old observations. The coarse circle is on the side of the clamp.

Examination of the Divisions of the Ann Arbor Meridian Circle.

The Ann Arbor Meridian Circle was originally furnished with two divided circles; but as the one on the side of the clamp was found to be slightly bent when it arrived at Ann Arbor, it is now used merely for setting the instrument, and only the one on the opposite side of the axis is used for reading the zenith distances. The four microscopes for reading the circle on each side are fastened by strong arms to a solid circular disc, which is firmly screwed to a solid brass piece let into the stone pillar. This disc supports at the same time the Y-pieces, so that the center of the axis coincides with its center. The edge of this disc is dove-

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tailed; and when the three screws which clamp the arms of the microscope are loosened, the arms can slide smoothly around the whole disc, and may be fastened with the greatest ease and with perfect stability to any point of the disc. By reason, however, of the width of the part of the arm which is clamped to the disc, the smallest distance within which any two microscopes can be brought is about 30°.

With the microscopes in their usual position, 90° distant from each other, I determined first the error of the line 180°, taking that of the line 0° equal to zero; and by bisecting the two arcs between the line 0° and the line of 180° corrected, I found the errors of the lines 90° and 270°. Then one microscope was placed at a distance of exactly 45° from the first; and by means of these two, and the other three microscopes at the respective distances of 90°, 180° and 270° from the first, I found the errors of the lines 45°, 135°, 225° and 315°, by bisecting arcs of 90° and 270° corrected according to the former observations. These observations of the lines at a distance of 45° were taken on eight different days, in temperatures ranging from 20° to 46° Fahrenheit. For each line, two observations were made, one immediately after the other; and the errors given in the following table are each deduced from the mean of two observations.

The errors of the lines distant 45° from each other, thus obtained on the different days mentioned, are as follows:—

1857.	45°	90°	135°	180°	225°	270°	315°	Temp.
November 25	+3.15″	+5.90″	+7.35″	+7.60″	+7.62″	+2.35″	−0.25″	19°
26	3.56	6.08	7.15	7.72	8.16	2.41	0.25	23
27	3.75	5.90	6.98	7.57	8.17	2.33	0.53	28
28	3.02	5.30	7.04	7.70	7.90	2.55	0.50	36.5
29	3.27	5.30	6.78	6.99	7.52	2.13	1.04	45
December 2	3.17	5.64	7.37	7.95	8.72	2.65	0.30	45.2
2	3.20	5.31	7.63	7.62	8.32	2.66	0.09	43.8
3	3.01	5.62	7.46	7.70	7.88	2.63	0.04	32.7
3	3.27	5.80	7.58	7.77	8.60	2.56	0.09	32.7
4	3.12	5.34	7.35	7.47	8.19	2.37	0.42	31.5
Mean	+3.25″	+5.62″	+7.26″	+7.61″	+8.11″	+2.46″	−0.35″	

The differences in the errors of the same line, found on different days, must have been caused by the different action of the temperature on different parts of the circle.

The same observations were repeated in the same manner, but in positions of the circle 180° different from those in the former series; and the following results were obtained, each result being the mean of two observations:—

1858.	45°	90°	135°	180°	225°	270°	315°	Temp.
January 1	+3.59″	+5.55″	+7.49″	+7.43″	+7.34″	+2.15″	−0.73″	35°
1	3.64	5.55	6.89	7.25	7.22	1.85	0.43	35.2
2	3.59	5.08	6.48	7.30	7.04	1.53	0.42	33.3
2	3.51	5.02	6.79	7.02	6.68	1.51	0.55	35.2
4	3.39	5.39	7.00	7.47	7.16	2.02	0.69	41.7
4	3.38	5.47	7.18	7.77	7.65	2.32	0.59	44.5
5	3.33	4.76	6.86	7.32	7.00	1.94	0.61	38.5
5	3.78	5.76	7.30	7.55	7.73	2.52	0.22	39.0
6	3.39	5.24	7.32	7.32	7.17	1.66	1.09	35.2
6	3.19	5.24	7.13	7.48	6.87	2.02	0.79	36.0
Mean	+3.48″	+5.30″	+7.04″	+7.39″	+7.19″	+1.95″	−0.61″	

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The mean errors of the seven lines, resulting from the two series of observations, are therefore:—

	45°	90°	135°	180°	225°	270°	315°
Error.....	+3.36"	+5.46"	+7.15"	+7.50"	+7.65"	+3.20"	—0.48"

In order to find the errors of the intermediate lines for intervals of 15°, I placed two microscopes exactly 105° apart: by means of these positions I divided arcs of 315° into three equal parts, beginning successively with the lines 0°, 45°, 90°, etc., and applying always the corrections for the seven principal lines found before. These observations were made on four days in one position of the circle, and on four other days in positions always 180° different. The same errors were found also by another series, with two microscopes placed 75° apart, arcs of 225° being divided into three equal parts: these observation ere likewise made on four days, and repeated on four other days in positions of the circle which differed always 180° from those in the former series. The following tables show the results found for the different errors on the different days:—

MICROSCOPES 105° APART.

	15°	30°	60°	75°	105°	120°	150°	165°	Temp.
December 12....	+0.45"	+0.80"	+3.21"	+5.45"	+6.57"	+6.50"	+6.97"	+8.21"	32.0°
14....	0.42	0.94	3.06	5.52	6.94	6.38	7.37	8.24	41.5
15....	0.17	0.94	3.28	5.53	6.31	6.46	7.64	8.44	43.7
January 7.....	0.62	1.24	3.14	6.58	6.21	6.13	7.64	8.28	32.0
Mean.....	+0.41"	+0.98"	+3.18"	+5.77"	+6.51"	+6.35"	+7.40"	+8.29"	

	195°	210°	240°	255°	285°	300°	330°	345°	Temp.
December 12....	+7.23"	+6.85"	+4.62"	+4.29"	+1.05"	+0.29"	—0.30"	- 1.51"	32.0°
14....	7.36	7.38	4.72	4.49	1.01	0.46	+0.08	1.31	41.5
15....	7.43	6.81	4.92	4.52	1.01	0.69	—0.37	1.11	43.7
January 7.....	6.93	6 31	5.02	4.52	1.31	0.19	+0.17	0.61	32.0
Mean.....	+7.24"	+6.84"	+4.82"	+4.45"	+1.10"	+0.41"	—0.14"	—1.13"	

CIRCLE 180° FROM ITS FIRST POSITIONS.

	15°	30°	60°	75°	105°	120°	150°	165°	Temp.
December 17....	+1.05"	+1.77"	+3.31"	+5.78"	+7.27"	+6.90"	+7.54"	+7.91"	40.3°
18....	1.15	1.50	3.88	6.28	7.64	7.40	7.41	8.54	38.5
19....	1.42	2.20	3.34	6.52	6.84	7.03	7.41	7.58	31.0
19....	1.85	2.14	3.72	6.52	6.84	7.60	7.54	8.06	30.3
Mean.....	+1.37"	+1.90"	+3.56"	+6.27"	+7.15"	+7.23"	+7.47"	+8.02"	

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	195°	210°	240°	255°	285°	300°	330°	345°	Temp.
December 17....	+6.76″	+6.65″	+4.79″	+4.12″	+2.18″	+0.26″	+0.17″	−1.08″	40.3°
18....	6.86	6.78	4.49	3.75	1.65	0.06	−0.43	1.68	38.5
19....	6.56	6.68	4.26	3.95	1.65	0.56	+0.63	1.75	31.0
19....	6.49	6.28	4.42	3.72	1.91	0.33	+0.83	1.31	30.3
Mean.....	+6.67″	+6.60″	+4.49″	+3.88″	+1.85″	+0.30″	+0.30″	−1.45″	

MICROSCOPES 75° APART.

	15°	30°	60°	75°	105°	120°	150°	165°	Temp.
December 12....	+0.02″	+1.45″	+3.93″	+6.28″	6.97″	+6.17″	+7.07″	+8.31″	33.2°
14....	0.56	1.48	4.27	6.58	7.04	6.24	7.47	7.68	44.0
15....	0.72	1.35	4.10	6.05	6.67	5.74	7.60	8.18	47.7
January 7.....	0.91	1.38	4.27	5.95	7.04	5.80	7.40	7.81	32.4
Mean.....	+0.56″	+1.41″	+4.14″	+6.21″	+6.93″	+5.99″	+7.38″	+7.99″	

	195°	210°	240°	255°	285°	300°	330°	345°	Temp.
December 12....	+6.69″	+7.37″	+4.47″	+4.09″	+1.58″	−0.41″	−1.33″	−2.08″	33.2°
14....	6.92	7.20	4.60	4.19	1.65	−0.25	1.23	2.02	44.0
15....	6.82	7.67	4.90	4.65	1.78	−0.01	0.19	1.85	47.7
January 7.....	6.56	7.27	5.07	4.52	2.08	+0.75	0.46	1.42	32.4
Mean.....	+6.75″	+7.38″	+4.76″	+4.35″	+1.77″	+0.02″	−0.80″	−1.84″	

CIRCLE 180° FROM ITS FIRST POSITIONS.

	15°	30°	60°	75°	105°	120°	150°	165°	Temp.
December 17....	+1.59″	+0.65″	+3.67″	+5.65″	+6.27″	+6.47″	+7.70″	+7.88″	40.8°
18....	1.69	1.28	3.83	5.38	7.04	5.87	7.47	8.11	38.3
19....	1.76	0.96	4.50	5.12	6.57	5.94	7.63	7.88	29.9
19....	1.52	0.68	4.30	5.45	6.34	6.17	7.70	8.05	30.3
Mean.....	+1.64″	+0.89″	+4.07″	+5.40″	+6.55″	+6.11″	+7.62″	+7.98″	

	195°	210°	240°	255°	285°	300°	330°	345°	Temp.
December 17....	+6.49″	+6.44″	+3.50″	+4.29″	+1.61″	+1.32″	+0.37″	−1.02″	40.8°
18....	6.29	6.37	3.77	4.52	2.08	1.72	0.54	1.08	38.3
19....	5.92	6.54	3.90	4.12	1.71	1.75	0.54	0.55	29.9
19....	6.19	6.34	3.83	4.12	1.61	1.59	0.34	0.65	30.3
Mean.....	+6.22″	+6.42″	+3.75″	+4.26″	+1.75″	+1.59″	+0.45″	−0.82″	

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Taking the mean of the results obtained in the two opposite positions of the circle, we find the following errors:—

	15°	30°	60°	75°	105°	120°	150°	165°
Microscopes 105° apart..	+0.89"	+1.44"	+3.37"	+6.02"	+6.83"	+6.79"	+7.43"	+8.15"
Microscopes 75° apart...	1.10	1.15	4.10	5.80	6.74	6.10	7.50	7.99
Mean.....	+1.00"	+1.30"	+3.73"	+5.91"	+6.78"	+6.45"	+7.46"	+8.07"

	195°	210°	240°	255°	285°	300°	330°	345°
Microscopes 105° apart..	+6.95"	+6.72"	+4.66"	+4.16"	+1.48"	+0.35"	+0.08"	−1.29"
Microscopes 75° apart...	5.49	6.90	4.26	4.31	1.76	0.81	−0.18	1.33
Mean.....	+6.77"	+6.81"	+4.46"	+4.23"	+1.62"	+0.58"	−0.05"	−1.31"

The errors of the lines separated by 5° were determined similarly to those for intervals of 15°, by placing the microscopes on four different days at distances of 85°, 95°, 100° and 110° apart; and thus arcs of 255°, 285°, 300° and 330° were each divided into three equal parts. The observations commenced successively with the lines 0°, 15°, 30°, etc, and the corrections for the first and last lines of the arc were applied according to the values given above. Thus the error of each line was found on different days by comparison with two different lines, so that the small uncertainty remaining in the errors of the lines 15°, 30°, 45°, 60°, 75°, etc., will have very little influence on the determination of the errors of the lines 5°, 10°, 20°, 25°, 35°, 40°, 50°, 55°, etc. These observations were likewise repeated on four days, with the circle at each time in a position 180° distant from the corresponding position in the former series.

The following table shows the result of all these observations:—

	5°	10°	20°	25°	35°	40°	50°	55°
December 21.....	+0.96"	−0.38"	+0.42"	+1.96"	+2.70"	+1.77"	+2.60"	+4.06"
23.....	1.23	−0.45	0.52	1.14	3.18	1.02	3.25	3.85
26.....	2.10	+0.05	0.35	1.69	2.69	1.67	3.22	3.97
29.....	1.51	−0.66	0.47	1.56	2.59	1.84	3.21	3.82
22.....	1.67	0.35	1.07	1.76	3.26	2.11	3.19	5.05
25.....	1.68	0.29	0.32	2.26	3.83	1.90	3.57	4.75
28.....	1.88	0.31	1.18	1.18	2.50	1.98	3.12	4.20
30.....	1.03	0.13	1.02	2.50	3.28	2.55	3.46	4.77
Mean.....	+1.51"	−0.31"	+0.67"	+1.76"	+3.00"	+1.86"	+3.20"	+4.31"

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	65°	70°	80°	85°	95°	100°	110°	115°
December 21	+4.51″	+3.57″	+4.59″	+6.28″	+6.84″	+4.61″	+5.63″	+6.51′
23	4.85	3.75	5.05	5.91	6.67	5.17	4.91	6.81
26	4.95	4.40	5.23	6.70	6.03	4.96	5.18	6.38
29	4.40	4.33	5.09	6.47	6.62	4.73	5.07	6.41
22	5.90	4.53	5.22	6.46	6.72	5.60	6.33	6.86
25	6.04	4.90	4.68	6.65	6.92	5.00	6.00	6.13
28	4.85	5.07	5.75	6.64	6.81	5.68	6.40	7.19
30	5.36	5.20	5.15	6.39	6.93	6.31	6.26	6.36
Mean	+5.11″	+4.47″	+5.10″	+6.44″	+6.69″	+5.26″	+5.72″	+6.58″

	125°	130°	140°	145°	155°	160°	170°	175°
December 21	+6.37″	+7.76″	+7.26″	+6.48″	+8.75″	+7.87″	+8.04″	+8.30″
23	6.11	7.43	7.35	6.66	8.70	7.72	7.42	8.70
26	6.70	6.51	6.37	7.06	9.31	7.66	8.25	8.89
29	7.01	6.58	7.10	6.37	8.43	7.92	7.72	9.07
22	6.35	7.63	6.73	7.06	8.08	8.10	6.78	8.40
25	6.72	6 98	7.38	6.21	8.50	7.02	7.89	8.27
28	7.60	7.47	7.40	7.34	8.73	7.63	7.26	8.61
30	7.64	7.04	7.87	7.41	8.82	7.92	8.18	8.21
Mean	+6.81″	+7.18″	+7.18″	+6.52″	+8 66″	+7.73″	+7.69″	+8.56″

	185°	190°	200°	205°	215°	220°	230°	235°
December 21	+7.97″	+8 28″	+7.82″	+7.25″	+7.82″	+6.05″	+6.41″	+7.25″
23	7.43	8 82	7.61	7.47	8.21	6.33	6.29	7.39
26	8.13	8.20	6.78	6.38	7.72	6.37	6.32	7.19
29	8.04	8 31	7.15	7.27	7.31	6.31	6.17	7.47
22	7.35	7.42	6.46	6.90	6.60	5.21	5.47	6.60
25	7.31	6.83	6.42	6.64	7.67	5.92	5.09	6.47
28	7.49	7.79	6.69	6.92	6.34	6.19	5.22	6.60
30	7.64	8.11	7.49	6.39	6.99	5.61	5.55	6.29
Mean	+7.67″	+7.97″	+7.05″	+6.91″	+7.33″	+6.00″	+5.81″	+6.91″

	245°	250°	260°	265°	275°	280°	290°	295°
December 21	+5 54″	+3.97″	+3.20″	+2.67″	+1.26″	+2.69″	+1.66″	+2.16″
23	5.64	3.82	3.45	2.90	2.03	1.80	1.88	1.97
26	5.09	3.03	3.56	2.95	1.33	2.08	1.09	1.64
29	4.48	3.86	3.31	2.44	1.64	1.58	1 55	2.03
22	5.11	3.59	2.79	1.13	1.02	2.30	1.02	1.32
25	4.13	3.05	3.04	1.92	0.46	1.91	1.47	1 36
28	4.44	2 86	2.68	2.29	0.63	1.37	1.04	1.37
30	4.98	2.93	2.67	1.20	1.09	1.70	1.14	1.49
Mean	+4.93″	+3.39″	+3.09″	+2.19″	+1.18″	+1.93″	+1.36″	+1.67″

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	305°	310°	320°	325°	335°	340°	350°	355°
December 21.....	+0.89"	+0.39"	—0.35"	—0.13"	—1.24"	—0.07"	+0.55"	—1.67"
23.....	1.02	+0.42	+0.03	—0.44	- 0.42	—0.46	+0.41	—1.98
26.....	0.67	—0.19	—0.39	—0.13	+0.03	—0.01	+0.61	—1.16
29.....	1.67	—0.04	- 0.43	—0.48	+0.19	—0.13	+0.56	—1.42
22.....	1.01	- 0.48	+ 0.19	—0.95	—1.36	—0.80	—0.01	—1.29
25.....	0.45	+0.42	—0.93	+0.31	—1.28	—0.13	—0.13	—1.66
28.....	0.37	—0.39	—0.53	—1.32	—1.10	—1.07	—0.39	—2.52
30.....	0.56	—0.44	—1.09	—0.21	—1.10	—0.96	—0.54	—1 62
Mean.....	+0.83"	—0.01"	—0.44"	—0.42"	—0, 78"	—0.49"	—0.13"	—1.66"

To show more distinctly how these observations compare with each other, I have taken the mean of the two observations made in the two opposite positions of the circle. These mean errors ought to be the same, if the observations were correct, and if the temperature had no influence on them. These means are given in the following table:—

	5°	10°	20°	25°	35°	40°	50°	55°
	+1.31"	—0.36"	+0.74"	+1.86"	+2.98"	+1.94"	+2.89"	4.55"
	1.46	0.37	0.42	1.70	3.51	1.46	3.41	4.30
	1.99	0.13	0.76	1.43	2.59	1.82	3.17	4.08
	1.27	0.39	0.74	2.03	2.94	2.20	3.34	4.30
Mean.....	+1.51"	—0.31"	+0.67"	+1.76"	+3.00"	+1.86"	+3.20"	+4.31"

	65°	70°	80°	85°	95°	100°	110°	115°
	+5.20"	+4.05"	+4.90"	+6.37"	+6.78"	+5.10"	+5.98"	+6.68"
	5.45	4.32	4.87	6.28	6.79	5 09	5 46	6.47
	4.90	4.73	5.49	6.67	6.42	5.32	5.79	6.78
	4.88	4.77	5.12	6.43	6 77	5.52	5.67	6.39
Mean	+5.11"	+4.47 '	+5.10"	+6.44"	+6.69"	+5.26"	+5.72"	+6.58"

	125°	130°.	140°	145°	155°	160°	170°	175°
	+6.36"	+7.69"	+7.00"	+6.77"	+8.41"	+7.98"	+7.40"	+8.35"
	6.41	7.21	7.36	6.44	8 60	7.37	7.66	8.48
	7 15	6.99	6.88	7.20	9.02	7.65	7.75	8.75
	7.32	6.81	7.48	6.89	8.63	7.92	7.95	8.64
Mean.....	+6.81"	+7.18"	+7.18	+6.82	+8.66"	+7.73"	+7 69"	+8.56"

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	185°	190°	200°	205°	215°	220°	230°	235°
	+7.66″	+7.85″	+7.14″	+7.07″	+7.21″	+5.63″	+5.94″	+6.92″
	7.39	7.82	7.02	7.08	7.94	6.13	5.69	6.93
	7.81	7.99	6.78	6.65	7.03	6.28	5.77	6.89
	7.84	8.21	7.32	6.83	7.15	5.96	5.86	6.88
Mean	+7.67″	+7.97″	+7.05″	+6.91″	+7.33″	+6.00″	+5.81″	+6.91″

	245°	250°	260°	265°	275°	280°	290°	295°
	+5.32″	+3.78″	+3.00″	+1.90″	+1.14″	+2.49″	+1.34″	+1.74″
	4.89	3.43	3.24	2.41	1.25	1.86	1.68	1.66
	4.76	2.93	3.12	2.62	0.98	1.72	1.05	1.50
	4.73	3.40	2.96	1.82	1.36	1.64	1.35	1.76
Mean.....	+4.93″	+3.39″	+3.09″	+2.19″	+1.18″	+1.93″	+1.36″	+1.67″

	305°	310°	320°	325°	335°	340°	350°	355°
	+0.95″	−0.05″	−0.08″	−0.54″	−1.30″	−0.43″	+0.27″	−1.48″
	0.73	+0.42	0.45	0.06	0.85	0.29	0.14	1.82
	0.52	−0.29	0.46	0.72	0.54	0.54	0.11	1.84
	1.11	−0.24	0.76	0.35	0.45	0.70	0.01	1.52
Mean.....	+0.83″	−0.04″	−0.44″	−0.42″	−0.78″	−0.49″	+0.13″	−1.66″

The errors of the division for every fifth degree are therefore as follows:—

0°	0.00″	75°	+5.91″	150°	+7.46″	225°	+7.65″	300°	+0.58″
5	+1.51	80	5.10	155	8.66	230	5.81	305	+0.83
10	−0.31	85	6.44	160	7.73	235	6.91	310	−0.04
15	+1.00	90	5.46	165	8.07	240	4.46	315	−0.46
20	+0.67	95	6.69	170	7.69	245	4.93	320	−0.43
25	+1.76	100	5.26	175	8.56	250	3.39	325	−0.42
30	+1.30	105	6.78	180	7.50	255	4.23	330	−0 05
35	+3.00	110	5.72	185	7.67	260	3.09	335	−0 78
40	+1.86	115	6.58	190	7.97	265	2.19	340	−0.49
45	+3.36	120	6.45	195	6.77	270	2.20	345	−1.31
50	+3.20	125	6.81	200	7.05	275	1.18	350	+0.13
55	+4.31	130	7.18	205	6.91	280	1.93	355	−1.66
60	+3.73	135	7.15	210	6.81	285	1.62		
65	+5.11	140	7.18	215	7.33	290	1.36		
70	+4.47	145	6.82	220	6.00	295	1.67		

The errors thus found are not merely those of the divisions, but include also the errors owing to the eccentricity of the circle and to the deviation of the pivots from a cylindrical form. The eccentricity produces terms of the form

$$a + b \cos x + c \sin x;$$

and from the 72 errors given above, I find the error of the eccentricity,

$$+4.''044 - 3.''835 \cos x + 1.''561 \sin x,$$

or $$+4.''044 - 4.141 \cos(x + 22° 9').$$

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If the error of the eccentricity of the circle be calculated for every fifth degree, and subtracted from the corresponding error in the table, the errors of the division will be as follows:—

0°	−0.21″	75°	+1.35″	150°	−0.69″	225°	+2.00″	300°	−0.19″
5	+1.15	80	+0.19	155	+0.48	230	+0.50	305	+0.26
10	−0.85	85	+1.18	160	−0.45	235	+1.95	310	−0.42
15	+0 26	90	−0.14	165	−0.08	240	−0.15	315	−0.71
20	−0.30	95	+0.76	170	−0.40	245	+0.68	320	−0.53
25	+0.53	100	−0.99	175	+0.56	250	−0.50	325	−0.42
30	−0.20	105	+0.24	180	−0.38	255	+0.70	330	+0.01
35	+1.20	110	−1.10	185	−0.06	260	−0.08	335	−0.69
40	−0.25	115	−0.50	190	+0.42	265	−0 63	340	−0.40
45	+0.92	120	−0.86	195	−0 57	270	−0.28	345	−1.25
50	+0.42	125	−0.71	200	−0 06	275	−0.97	350	+0.13
55	+1.19	130	−0.52	205	+0.05	280	+0.09	355	−1.76
60	+0.25	135	−0.71	210	+0.23	285	+0.08		
65	+1.27	140	−0.80	215	+1.04	290	+0 09		
70	+0.27	145	−1.26	220	+0.02	295	+0 66		

It is evident that these errors have two regular periods; one depending on the double angle, the other having itself a period of ten degrees. From the 72 errors, I find the following expression for these periodical errors of the division:—

$$-0.603 \cos (2x+74^\circ\ 20') - 0.''23 \cos 36x.$$

The first term shows that the circle has a small ellipticity; the latter very probably arises from the manner in which the division was made. The introduction of these two terms brings the sum of the squares of the errors from 39.7 down to 22.9.

If we subtract these periodical errors from the errors of the preceding table, we find at last that the errors of the lines with intervals of five degress, considered as merely accidental, become as shown in the following table:—

0°	+0.18″	75°	+0.69″	150°	+0.12″	225°	+1.19″	300°	+0.46″
5	+0.98	80	+0.07	155	+0.80	230	+0.13	305	+0.52
10	−0.67	85	+0.69	160	+0 28	235	+1.12	310	+0.35
15	−0.12	90	−0.07	165	+0.12	240	−0.50	315	−0.36
20	−0 32	95	+0.47	170	+0.18	245	−0.10	320	+0 30
25	−0.04	100	−0.71	175	+0.59	250	−0.77	325	−0.05
30	−0.39	105	+0.16	180	+0.01	255	+0.04	330	+0.82
35	+0.48	110	−0.62	185	−0.23	260	−0.20	335	+0.37
40	−0.57	115	−0.39	190	+0.60	265	−1 12	340	+0.33
45	+0.11	120	−0.21	195	−0.95	270	−0.21	345	− 1.05
50	+0.05	125	−0.45	200	− 0.08	275	−1.26	350	+0.71
55	+0.36	130	+0.25	205	−0.52	280	+0 37	355	− 1.73
60	−0.10	135	0.36	210	+0 04	285	0 00		
65	+0.49	140	+0.03	215	+0.32	290	+ 0.57		
70	0.00	145	−0 89	220	−0.30	295	+0.77		

The probable error of any line is equal to ± 0.″38; and therefore the probable error of the mean of four lines which are used in reading the microscopes, is ± 0.″19.

With regard to the numbering of the degrees as given by Dr. Brünnow, he refers, I think, to zenith distances when the circle is in a particular position on the axis. See Publications of the Dunsink Observatory, Part IV, page 12, where the division marks whose errors have been determined by Dr. Brünnow are taken in this way. See, also, the Abhandlungen of

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Bessel, edited by Engelmann, Band II, s. 76. I made an examination of the errors of several of the five degree marks, taken according to my notation, and found results so different from those of Dr. Brünnow that I think they can only be explained as above.

Discussions of the Pistor and Martins circles can be found also in the Annals of the Leiden Observatory, the volumes of the Naval Observatory, Washington, and in articles by Professor Boss, in Gould's Astronomical Journal. As I understand it, the divisions of these circles were probably made by means of successive applications of different standards. Thus the 10° marks were first cut. Then these intervals were bisected. Then the singles degrees were cut by starting from the 5° marks, and applying successively a standard degree, and so on. Thus, there would be a cumulative error arising from the error of the standard, to be combined with the probable error of the placing of the standard in position. It would hardly answer, therefore, in the case of these circles, to determine the division errors of the 5° lines, and then interpolate between them. For ordinary work the safest way might be to turn the circle frequently on the axis, and not apply any division errors at all. Both circles go on tapering axes, and are pushed up by collars held by screws, so that the circles can be revolved into any position.

Counting the circle divisions in the manner I have adopted, the following lines have been used for Polaris and the nadir in the observations published in this paper, the readings being those given under microscope I when the clamp is east.

For the Nadir 71° 32'—34'.
For Polaris

Above pole	205°	04'—06'		Below pole	202°	36'—38'	
Reflected	118	00—02		Reflected	120	28—30	

Since the divisions used for the Polaris observations were not changed during this series, the errors would not enter into the computation of the aberration constant. But for the purpose of examining the latitude as found from these observations a determination was made of the special marks according to the method described by Bessel in the Abhandlungen. The mean of the divisions 0°, 90°, 180°, 270° is supposed to have no error. The errors as determined are the means of the errors of the four marks pointed on with the microscopes.

205° 04'

Position 1.	Position 2.
+0.17"	−1.14"
+0.32	−1.20
−0.10	
+0.59	−1.17
+0.24	

−0.46"

202°

Position 1	Position 2.
−0.81"	+0.32"
−0.96	+0.44
−0.88	+0.38

−0.25"

118° 00'

Position 1.		Position 2.
+0.54"		−0.39"
+0.30	wt ½	−0.41
+0 58		
+0.51		−0.40

+0.06"

120° 28'

Position 1.	Position 2.
−0.38"	+0.60"
+0.16	+0.64
−0.11	+0.62

+0.26"

71° 32'

Position 1.	Position 2.
+0.20"	+0.40"
+0.03	+0.31
+0.03	−0.39
+0.09	+0.11

+0.10"

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In position 2 the microscopes are changed 180° from the first position. Evidently the effect of gravity on the circle is considerable. The division errors are to be added to the actual readings to produce the ideal.

As to the marks 205° 06′, 202° 38′, etc., the errors were found by comparing the spaces 205° 04′-06″, etc., with the mean of a good many 2′ spaces on the circle, this mean being regarded as the true value of a 2′ space. For the required 2′ spaces we have then the following values, it being understood that 71° 32′-34′ for instance, refers to the mean of the four spaces 71° 32′-34′, 161° 32′-34′, 251° 32′-34′, 341° 32′-34′.

Space 71° 32′-34′. Reduction to mean 2′ space.	Space 118° 00′-02′. Reduction.	Space 120° 28′-30′. Reduction.
−0.47″	+0.01″	+0.37″
−0.50	+0.16	+0.24
+0.01	−0.18	+0.49
−0.27	−0.24	+0.60
−0.07	+0.08	+0.15
−0 33	−0.03	+0.37
−0.03		
−0.45		
−0.51		
−0.37		
Mean.... −0.30		

Space 205° 04′-06′. Reduction.	Space 202° 36′-38′. Reduction.
+0.26″	+0.28″
+0.18	+0.24
+0.14	−0.06
−0.03	−0.60
−0.20	−0.10
+0.07	−0.05

Finally, for the errors of the divisions employed in this work

Division.	Error.
205° 04′	−0.46″
205 06	−0.53
Mean.....	−0.50

Division.	Error.
202° 36′	−0.25″
202 38	−0.20
	−0.22

Division.	Error.
118° 00′	+0.06″
118 02	+0.09
	+0.08

Division.	Error.
120° 28′	+0.26″
120 30	−0.11
	+0.08

Division.	Error.
71° 32′	+0.10″
71 34	+0.40
	+0.25

9.—*Eccentricity of Fine Circle.*

The eccentricity of the fine circle was determined by pointing on the 10° lines, first with microscopes I and III, and then with II and IV, the instrument being clamp east. The readings were made so as to eliminate progressive changes proportional to the time. Thus are obtained the following values for $\underline{O}$ and $\frac{e}{r}$, $\underline{O}$ being the direction of the line joining the center of the circle to the center of revolution, e the distance between the centers, and r the radius of the circle:

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Microscopes III and I.		Microscopes IV and II.	
$\frac{e''}{r} = 4.41''$	O = 180° 07′	$\frac{e''}{r} = 4.13''$	O = 182° 04′
4.08	179 37	3.61	176 32

The above values give for the means

$$\frac{e''}{r} = 4.04'' \quad O = 179° 35'.$$

In order to reduce an actual reading on the circle, A′, to a reading A, counted at the center of the circle, we have

$$A = A' - \frac{e''}{r} \sin (A' - O).$$

10.—The Microscopes.

These are supported on arms which are clamped to the brass discs described in article *3*. This arrangement seemed to me at first not a good one, but in fact the arms do not move much, and the nadir determinations agree as well as those made with other instruments. This plan of mounting the microscopes I have heard criticised, however, by a number of experienced observers.

To the brass discs which hold the microscope arms I had brackets attached, and these brackets carry fine screws which butt against the arms, making it possible to adjust them easily.

Illumination is obtained by means of little electric lamps attached to the ends of the microscopes, the light coming in at right angles to the line of sight, and being reflected against the circle by a plaster of Paris surface. The lamps are somewhat near the circle, but as they are lighted only for an instant I think there is no danger of heating it. The light is furnished from chloride accumulator cells which are charged from the University lighting plant. The microscopes are of low magnifying power, about 16. The power should be considerably greater.

The periodic errors of the screws were found as described by Professor Newcomb in the Washington Observations for 1865, by measuring the interval between the parallel wires of each microscope, bringing each wire near a circle division and separating it from this division by a distance equal to its own thickness. In this way the periodic errors for the respective microscopes were found to be

I	−0.062″ cos u	+0.033″ sin u
II	−0.186 cos u	+0.231 sin u
III	+0.004 cos u	+0.067 sin u
IV	−0.012 cos u	+0.075 sin u

For clamp east I is lower microscope on north side, II is upper on north side, III upper on south side, and IV lower on south side.

For clamp west I is lower on south side, II upper on south side, III upper on north side, and IV lower on north side. The microscopes were taken in this way for my own convenience in recording.

On September 19, 1899, I happened to loosen the divided head of microscope IV, and turned it on the shank.

The periodic error was then found to be

$$\text{IV} \quad +0.057'' \cos u \quad +0.039'' \sin u$$

On May 10, 1900, the spider lines of two of the microscopes became loose, owing to the use of too much oil on the screws, the oil working on to

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the slides and touching the threads. New lines were inserted and the screws were mounted in a small lathe and cleaned. Though I requested that the positions of the divided heads on the shanks be carefully marked this was not done, and large periodic errors were found after the return of the microscopes. I think that when the instrument was made the microscope heads were placed on the shanks and divided so as to eliminate the periodic errors of the screws. Therefore I made a number of attempts to find the proper positions of the heads, but was not able to do it in the time at my disposal.

For the period, then, 1900, May 10 to June 6 we have the following values of the periodic errors, these being determined by measuring the distance between a division and a well defined speck of dirt found on the circle, rather a better method, I think than the one spoken of above:

$$\begin{array}{rrrrr} \text{I} & -0.576'' & \cos u & -0.288'' & \sin u \\ \text{II} & -0.280 & \cos u & -0.738 & \sin u \\ \text{III} & -0.147 & \cos u & -0.047 & \sin u \\ \text{IV} & +0.026 & \cos u & +0.040 & \sin u \end{array}$$

After 1900, June 6, we have for microscopes I, II and IV

$$\begin{array}{rrrrr} \text{I} & +0.036'' & \cos u & -0.502'' & \sin u \\ \text{II} & -0.052 & \cos u & +0.014 & \sin u \\ \text{IV} & +0.014 & \cos u & +0.107 & \sin u \end{array}$$

In the case of III we have after June 6, 1900, and before July 14, 1900

$$\text{III} \quad +0.532'' \cos u \quad +0.352'' \sin u$$

After 1900, July 14

$$\text{III} \quad +0.176'' \cos u \quad +0.758'' \sin u.$$

In the summer of 1901 I made another determination of the periodic errors which agreed with the final values as given above.

It would be better to arrange to eliminate periodic errors, perhaps by using two pairs of threads, 1.5 revolutions apart.

The progressive errors of the microscope screws are negligible throughout the interval in which they were employed.

It requires about one day to reverse this meridian circle and readjust the microscopes.

11.—The Collimating Telescopes.

These are small, having as approximate dimensions: diameter of object glasses 2.094 inches, focal length 2 feet, power of eye-pieces 38, distance between wyes 11.2 inches. The three screws which support each telescope-stand are at the vertices of an equilateral triangle a side of which is 9.1 inches. Each stand is adjustable in level and azimuth.

A number of attempts were made to obtain the flexure of the meridian circle by means of the collimators, but I was never able to level them with a delicate level, and finally gave it up.

12.—Flexure.

The flexure coefficients were determined from observations of known stars, it being assumed that the effect can be expressed in the form

$$a_1 \sin z + b_1 \cos z + a_2 \sin 2z + b_2 \cos 2z, \text{ etc.}$$

Then calling Z the true zenith distance we have for direct and reflected observations, N being the nadir reading of the circle,

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$$Z = z_1 + a_1 \sin z + b_1 \cos z + a_2 \sin 2z + b_2 \cos 2z - (180° + N) + b_1 - b_2 \quad (1)$$

$$180° - Z = z_2 + a_1 \sin z - b_1 \cos z - a_2 \sin 2z + b_2 \cos 2z - (180° + N) + b_1 - b_2 \quad (2)$$

After the instrument is reversed the corresponding formulas are

$$360 - Z = z_3 - a_1 \sin z + b_1 \cos z - a_2 \sin 2z + b_2 \cos 2z - (180° + N) + b_1 - b_2 \quad (3)$$

$$180° + Z = z_4 - a_1 \sin z - b_1 \cos z + a_2 \sin 2z + b_2 \cos 2z - (180° + N) + b_1 - b_2 \quad (4)$$

By combining formulas (1) and (3) the cosine coefficients can be obtained. Accordingly stars were observed north and south of the zenith in both positions of the instrument for this purpose.

From 22 south stars is obtained

$$b_1 = -1.43'', \; b_2 = -0.47$$

and from 26 north stars

$$b_1 = -1.50'', \; b_2 = -0.49''.$$

The term b_2 seems really to exist, though it will require a good many observations to determine it with accuracy, since the weights of observations made at large zenith distances are small. The following table of approximate weights has been computed with the zenith distance as argument:

z	Weight.	z	Weight.
0°	4.4	65°	2.7
10	4.4	70	2.3
20	4.2	75	1.5
30	4.0	80	0.9
40	3.7	81	0.8
45	3.3	82	0.7
60	2.9		

By measuring the distance on the circle between north and south stars of about 60° zenith distance the coefficient a_1 of the sine flexure was obtained,

$$a_1 = +1.20''.$$

Some attempts were made to find the flexure coefficients by treating the north and south stars separately. But the cosine coefficients enter with such large relative weights that the process is not accurate. It was necessary to insert, also, a term to represent any correction of the latitude, and this has a large relative weight. The latitude was assumed to be +48° 16′ 49.3″.

Taking then the north and south stars separately, these values were obtained:

	a_1	b_1	$\Delta\phi$
Clamp West—			
North stars	+1.72″	−2.30″	+0.40′
South stars	+1.00	−1.50	−0.36
Clamp East—			
North stars	+0.72	−1.00	+0.03
South stars	+2.59	−1.66	−0.53

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Combining all the stars used for flexure we find:

	a_1	b_1	$\Delta\phi$
Clamp West	+1 00″	−2.10″	+0.51″
Clamp East	+1.37	−1.12	−0.38

The flexure as found represents the combined effect on the circle and telescope, which as yet has not been separated into the two parts. Such a term as b_1 in the flexure of the telescope proper would be caused, I suppose, by the axis of symmetry of the telescope not coinciding with the neutral axis.

As has been stated the value of ϕ was assumed +48° 16′ 49.3″, and $\Delta\phi$ is the correction to be added to this. In order to check the value of $\Delta\phi$ I have assumed the values $a_1 = +1.20''$, $b_1 = -1.46''$, and have used only stars near the zenith for computing this quantity, with the following results:

Clamp East—South stars $\Delta\phi$ =	−0.53″
North stars	−0.85
Clamp West—South stars	−0.31
North stars	−0.66
Mean.....	−0.58

For the present, the latitude can be assumed

+42° 16′ 48.8″.

Situated as we are, an elaborate determination of the division errors cannot be made, so that it will be necessary to secure more values of the latitude, turning the circle on its axis, and observing direct and reflected, and clamp east and west. From my experience with large, heavy instruments I do not believe much in the application of such corrections as those of flexure and division error, but think that observations should be arranged as far as possible so as to eliminate all such quantities.

The flexure seems to be rather constant. Before beginning observations of Polaris, I had the foreman of the University engineering shops examine the screws which hold the telescope cones to the cube. It was his opinion that I had driven them up too tight, and, therefore, they were loosened a trifle.

13.—Meteorological Instruments.

The standard barometer was examined at Ann Arbor by Professor Marvin of the Weather Bureau Office in the summer of 1892. It was found to be badly out of order, and in trying to make repairs the glass tube was broken. The instrument was then taken to the Weather Bureau Office in Washington, and a new tube was filled and inserted. Also, a new attached thermometer was put on, since the old one was found 1° in error.

Our thermometers, also, have been examined by the Weather Bureau and I have to thank the officials in Washington and Lansing for the considerable attention which they have paid to our meteorological instruments.

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For refractions Bessel's tables were used as prepared by Professor J. R. Eastman for the Naval Observatory. The thermometer was hung near the object glass of the telescope. For daytime observations of Polaris as much as possible of the open slit was covered with canvas, and a large piece of canvas was pulled up over most of the roof, which is tin, the canvas being spread some time before observing. However, with any such observing room as ours there must be some uncertainty regarding the refraction, but I did not feel like attempting any reduction for the condition of the room. I was careful to air it for several hours before working.

14.—The Nadir.

This was determined over a shallow basin of iron, the concave part, which holds the mercury, being plated with copper. The basin was turned 180° in the middle of any series of observations. As stated, all zenith distance settings were made with the tangent screw, there being no micrometer for that cordinate. To observe the nadir it was necessary to run up two small rods connected with Hooke's joints, and supported by large rods held by the microscope arms of the coarse circle.

A complete determination of the nadir includes four settings, two divisions on the circle being read after each setting. All nadir observations were made facing north. For observations of Polaris the nadir was taken immediately before and immediately after the zenith distance pointings. If it is assumed that the difference between the nadir at the beginning and that at the end of a series is due only to accidental errors, we have for the probable error of a complete nadir determination, four pointings,

$$\pm 0.28''$$

and for the mean of two determinations,

$$\pm 0.20''.$$

The above results for the probable error of a nadir determination are a little larger than is the case with some instruments. The values as given include the error from the circle readings. The microscopes are of low power, about 16.

The number of observations examined was 77. The mean of each night's nadir was regarded as the true value. Thus two residuals were formed for each observation. Then for the 77 observations $[vv]=133100$, the unit being $0.01''$.

A smaller probable error for a nadir determination would be found by comparing among themselves the separate nadir pointings. In this way is obtained $[vv]=284942$, the unit being $0.01''$. Then for the probable error of a single nadir pointing including the reading of the circle is found the value $\pm 0.194''$, the number of single pointings considered being 646. For the mean of four settings, then, or a complete determination of one nadir, is obtained $0.10''$. These smaller values I think are fictitious.

15.—Inclination of Horizontal Threads.

The pointings on Polaris were made symmetrically on each side of the meridian so as to eliminate the inclination of the horizontal threads. These are about $5''$ apart, the object pointed on being placed midway between them.

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I have examined the wire inclination during the periods 1898, May 23.4 to June 14.3 inclusive, and December 10.3 to December 27.8 inclusive, taking account of the change of refraction during each day's observation. Calling the effect of the inclination of the horizontal threads $\cos \delta \sin t. I$, where t is the hour angle and I the inclination, the values of I for the two periods as determined from Polaris are:

Telescope clamp east, Polaris direct, East zenith distances too great, or E. ends of threads too high.

	I.		I.
1898.		1898.	
May 23.4	+59.0″	December 10.3	−90.5″
24.9	+57.9	12.8	+146.2
25.4	−13.6	13.3	+176.0
25.9	+80.3	13.8	+30 4
26.9	−45.9	15 3	+59.0
30.3	+152.2	15.8	+152.6
30.8	+24.6	17.3	−26.5
		18.3	+159.0
June 1.3	+73.0	24.3	+224.1
2.8	+65.8	27.3	+74.5
3.4	+44.5	27.8	+64.6
6.8	+89.5		
14.5	+113.9		
Sum	+701.2″	Sum	+969.4″
Mean	+58.4″	Mean	+88.1″

16.—Probable Error of Single Pointing on Polaris.

If it is assumed that the value of I for the first period referred to in article 15 is 58.4″, and for the second period 88.1″, it is possible to compute the probable error of a single pointing for each date taken separately. The nadir used on each date is the mean of the observed nadirs, and the reading of the circle is included with the pointing.

Probable error of a single pointing on Polaris.

	Number pointings.	Probable error pointing.		Number pointings	Probable error pointing.
1898.			1898.		
May 23.4	7	±0.25″	December 10.3	7	±0.40″
24.9	7	±0.36	12 8	7	±0 45
25.4	7	±0.48	13.3	7	±0.43
25.9	7	±0.2[illegible]	13.8	7	±0 29
26.9	7	±0.33	15.3	7	±0.08
30.3	7	±0.41	15.8	5	±0.22
30.8	7	±0 35	17.3	7	±0 27
			18.3	7	±0.33
June 1.3	7	±0 25	24.3	5	±0.37
2 8	7	±0 31	27.3	7	±0.52
3.4	7	±0.21	27.8	7	±0.35
6.8	7	±0.42			
14 3	7	±0.35			

The probable error of a single pointing is taken as ± 0.33″.

For the mean of 7 pointings the probable error is ± 0.13″. Compounding this with ± 0.20″, the probable error of the mean of two nadir determina-

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tions, we obtain for the probable error of the corresponding zenith distance ± 0.24″. This quantity is to be combined with the probable error of the refraction tables, which for Polaris may be taken as ± 0.3″. So that for one observation of 7 pointings the total probable error is ± 0.38″.

In ordinary observations the uncertainty of the division marks should be included as well as that of the flexure.

17.—Observations of Polaris.

At first the conditions imposed on the observations were too severe. I attempted to obtain always successive culminations, and at each culmination both direct and reflected observations. On account of the weather and duties of instruction it was necessary to give up the idea of observing only successive culminations, and being for most of the time without a recorder I could not make observations both direct and reflected without working rather near to the edge of the field.

Since the direct observations above and below pole extend over about the same periods of time, the latitude variation will be eliminated from the determination of the aberration constant, as well as other disturbances of a like nature, including changes in the flexure.

It is planned to take more of these observations and with some assistance the necessary frequent reversals could be made, in order to determine the latitude variation with accuracy.

The following are the observations of Polaris corrected for refraction and reduced to the meridian. For each observation seven pointings were usually taken, though sometimes five or nine. However, each observation has been given the same weight.

For reduction to the meridian has been used the expression

$$\sin 2\,\delta.\ \frac{\sin^2 \tfrac{1}{2}(T-m)}{\sin 1''}$$

In this, δ is the apparent declination as taken from the ephemeris, and the single term is sufficient.

All the declinations of Polaris have been taken from the Berliner Jahrbuch. An account of the terms included in the computation of apparent places is given in the Jahrbuch for 1884.

The reduction to 1900.0 is given in order that the observations may be compared among themselves.

The nadirs for any observations were interpolated when they differed more than 0.3″.

The images and steadiness are marked on the scale 1-5, 1 being perfect.

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OBSERVATIONS OF POLARIS., CLAMP EAST. NADIRS.

Date.	Sid. T. H.	Sid. T. M.	Nadirs.	Sid. T. H.	Sid. T. M.	Nadirs.
1898.						
April 25.9	0	26	71° 33' 08.58"	2	23	71° 33' 07.96"
26.9	0	35	71 33 08.54	2	23	71 33 07.76
May 5.9	0	17	71 33 07.24	2	18	71 33 06.70
8.9	0	7	71 33 06.70	2	14	71 33 05.76
16.9	0	15	71 33 06.13	2	15	71 33 05.36
24.9	0	22	71 33 04.76	2	12	71 33 04.53
25.9	0	23	71 33 08.31	2	10	71 33 08.34
26.9	0	22	71 33 10.12	2	13	71 33 10.24
30.9	0	25	71 33 11.66	2	12	71 33 11.11
June 2.8	0	23	71 33 6.24	2	15	71 33 6.07
6.8	0	31	71 33 5.50	2	20	71 33 5.08
16.8	0	16	71 33 2.74	2	17	71 33 2.89
19.8	0	11	71 33 2.63	2	10	71 33 3.14
20.8	0	20	71 33 2.02	2	22	71 33 3.18
22.8	0	26	71 33 2.60	2	15	71 33 3.07
July 5.8	0	27	71 33 7.80	2	22	71 33 7.88
7.8	0	35	71 33 5.42	2	13	71 33 5.08
10.7	0	12	71 33 6.52	2	20	71 33 7.00
13.7	0	30	71 33 4.92	2	27	71 33 5.20
20.7	0	07	71 33 7.64	2	22	71 33 8.75
21.7	0	18	71 33 7.22	2	15	71 33 7.60
22.7	0	19	71 33 6.22	2	13	71 33 7.02
25.7	0	19	71 33 6.21	2	11	71 33 6.30
26.7	0	27	71 33 4.70	2	09	71 23 5.17
August 4.7	0	11	71 33 3.40	2	14	71 33 3.00
9.7	0	17	71 33 5.03	2	20	71 33 5.22
13.7	0	10	71 33 7.04	2	19	71 33 6.78
19.7	0	08	71 33 5.58	2	13	71 33 4.78
25.6	0	22	71 33 0.00	2	11	71 33 0.06
26.6	0	14	71 33 0.86	2	11	71 33 1.16
September 24.5	0	29	71 33 0.97	2	18	71 33 0.50
26.5	0	25	71 33 4.62	2	14	71 33 3.43
28.5	0	28	71 32 58.64	2	16	71 32 57.82
October 8.5	0	35	71 33 0.45	2	24	71 33 1.56
11.5	0	18	71 33 1.26	2	22	71 33 0.82
27.4	0	27	71 32 59.75	2	17	71 32 59.59
31.4	0	32	71 33 4.13	2	10	71 33 4.17
November 7.4	0	46	71 33 3.12	2	23	71 33 3.00
12.4	0	30	71 32 59.42	2	16	71 32 59.49
13.4	0	30	71 32 58.14	2	15	71 32 58.07
26.4	0	21	71 33 1.14	2	14	71 33 0.64
December 10.3	0	17	71 32 54.12	2	25	71 32 54.20
13.3	0	32	71 33 6.90	2	14	71 33 6.67
15.3	0	20	71 33 7.94	2	46	71 33 7.48
17.3	0	15	71 33 10.75	2	11	71 33 10.40
31.3	0	7	21 32 55.66	2	12	71 32 54.39
1899.						
January 2.3	0	21	71 32 57.78	2	27	71 32 57.82
9.2	0	10	71 33 1.56	2	32	71 33 1.06
14.2	0	47	71 33 0.20	2	00	71 33 0.32
21.2	0	17	71 33 0.83	2	09	71 33 1.36
24.2	0	30	71 32 58.30	2	08	71 32 57.94
31.2	0	42	71 32 56.14	2	17	71 32 56.26
February 8.2	0	27	71 32 57.16	2	35	71 32 56.96
13.2	0	12	71 32 43 96	2	27	71 32 43.18
16.2	0	37	71 32 58.06	2	00	71 32 58.40
24.1	0	27	71 33 21.68	2	20	71 33 22.56
March 1.1	0	41	71 33 0.58	2	07	71 33 1.29
April 4.0	0	22	71 33 0.22	2	37	71 32 59.10
9.0	0	18	71 33 0.88	2	13	71 33 0.18
18.9	0	25	71 32 57.00	2	03	71 32 56.38
20.9	0	25	71 32 57.27	2	07	71 32 57.50
23.9	0	21	71 32 57.48	2	05	71 32 57.83
25.9	0	21	71 32 58.08	2	00	71 32 58.37
27.9	0	43	71 32 54.94	2	06	71 32 54.32
28.9	0	21	71 32 58.64	2	00	71 32 58.22

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OBSERVATIONS OF POLARIS. CLAMP EAST. NADIRS.

Date.		Sid. T. H.	Sid. T. M.	Nadirs.			Sid. T. H.	Sid. T. M.	Nadirs.		
	1899.										
May	8.9	0	37	71°	32′	57.38″	2	05	71°	32′	57.63″
	10.9	0	32	71	32	58.01	2	15	71	32	57.88
	23.8	0	25	71	32	58.42	2	10	71	32	58.66
	24.8	0	32	71	32	57.75	2	12	71	32	57.92
June	1.8	0	42	71	32	57.53	2	15	71	32	58.09
	3.8	0	40	71	32	58.06	2	10	71	32	57.80
	4.8	0	30	71	32	58.99	2	21	71	32	59.14
	29.7	0	06	71	32	57.84	2	00	71	32	58.39
July	8.7	0	16	71	32	57.02	2	20	71	32	58.34
	10.7	0	24	71	32	57.45	2	18	71	32	57.82
	18.7	0	17	71	32	57.98	2	13	71	32	58.02
	22.7	0	15	71	33	1.76	2	12	71	33	1.98
August	10.7	0	29	71	32	57.94	2	18	71	32	58.36
	12.7	0	20	71	32	56.60	2	15	71	32	58.00
	13.7	0	23	71	32	54.87	2	16	71	32	56.42
September	1.6	0	33	71	32	58.12	2	16	71	32	58.38
	11.6	0	21	71	32	57.77	2	18	71	32	57.87
	13.5	0	15	71	32	59.06	2	17	71	32	59.26
	26.5	0	31	71	32	55.18	2	21	71	32	55.21
	30.5	0	40	71	32	55.42	2	14	71	32	55.64
October	2.5	0	10	71	32	55.20	2	25	71	32	54.82
	1898.										
April	26.4	12	29	71°	33′	8.14″	14	10	71°	33′	7.14″
	27.4	12	31	71	33	7.76	14	13	71	33	7.72
May	5.4	12	25	71	33	7.32	14	12	71	33	7.36
	7.4	12	22	71	33	6.39	14	13	71	33	5.98
	9.4	12	20	71	33	6.62	14	10	71	33	5.80
	23.4	12	44	71	33	4.37	14	30	71	33	4.10
	25.4	12	23	71	33	4.50	14	07	71	33	4.21
	30.3	12	35	71	33	12.20	14	15	71	33	12.02
June	1.3	12	40	71	33	6.38	14	05	71	33	6.28
	3.3	12	27	71	33	6.66	14	13	71	33	5.98
	14.3	12	31	71	33	4.35	14	10	71	33	4.92
	17.3	12	27	71	33	2.44	14	14	71	33	2.34
	21.3	12	26	71	33	2.10	14	10	71	33	2.17
	22.3	12	28	71	33	2.44	14	16	71	33	2.81
July	6.2	12	12	71	33	5.53	14	15	71	33	5.44
	9.2	12	24	71	33	6.13	14	10	71	33	6.33
	11.2	12	20	71	33	5.48	14	12	71	33	5.36
	12.2	12	28	71	33	6.20	14	13	71	33	5.85
	14.2	12	38	71	33	5.80	14	12	71	33	5.57
	21.2	12	7	71	33	6.04	14	08	71	33	5.76
	22.2	12	18	71	33	5.72	14	15	71	33	5.90
	29.2	12	13	71	33	4.90	14	12	71	33	5.29
August	2.2	12	19	71	33	4.63	14	14	71	33	4.63
	4.2	12	10	71	33	4.18	14	25	71	33	4.06
	10.2	12	06	71	33	8.00	14	15	71	33	7.72
	25.1	12	09	71	33	1.76	14	20	71	33	1.50
	26.1	12	16	71	33	0.62	14	14	71	33	0.86
	27.1	12	26	71	33	0.62	14	00	71	33	0.67
September	25.0	12	15	71	33	2.05	14	14	71	33	1.83
	27.0	12	5	71	33	2.94	14	11	71	33	3.52
	29.0	12	20	71	33	6.32	14	19	71	33	6.78
October	9.0	12	30	71	33	1.63	14	12	71	33	1.90
	14.9	12	31	71	33	1.82	14	18	71	33	1.42
	24.9	12	42	71	33	0.67	14	14	71	33	0.64
	26.9	12	10	71	32	59.90	14	18	71	33	0.04
November	2.9	12	35	71	33	4.64	14	16	71	33	4.77
	15.9	12	23	71	33	3.72	14	20	71	33	4.58
	24.8	12	11	71	33	1.16	14	18	71	33	1.56

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OBSERVATIONS OF POLARIS. CLAMP EAST. NADIRS.

Date.	Sid. T. H.	Sid. T. M.	Nadirs.	Sid. T. H.	Sid. T. M.	Nadirs.
1898.						
December 12.8	12	22	71° 33′ 7.12″	14	10	71° 33′ 6.37″
13.8	12	27	71 33 6.38	14	22	71 33 6.23
15.8	12	19	71 33 7.79	14	29	71 33 8.19
28.8	12	24	71 33 0.17	14	18	71 33 0.20
1899.						
January 6.8	12	25	71 32 54.62	14	17	71 32 54.81
9.7	12	16	71 33 0.84	14	15	71 32 59.52
14.7	12	45	71 32 59 79	14	00	71 33 0.02
26.7	12	26	71 32 55.67	14	25	71 32 55.88
31.7	12	20	71 32 55.92	14	32	71 32 56.20
February 6.7	12	35	71 32 58.46	14	37	71 32 58.55
13.7	12	27	71 32 55.43	14	38	71 32 53.90
24.7	12	39	71 32 56.01	14	22	71 32 56.70
27.6	12	30	71 32 59.16	14	11	71 32 59.72
March 23.5	12	22	71 32 55.08	14	05	71 32 55.64
April 8.5	12	35	71 33 0.46	14	00	71 33 0.69
9.5	12	17	71 32 59.35	14	14	71 32 58.48
10.5	12	00	71 32 58.55	14	02	71 32 58.64
20.4	12	16	71 32 57.47	14	11	71 32 56.28
22.4	12	33	71 32 57.21	14	13	71 32 57.30
25.4	12	25	71 32 57.94	14	15	71 32 57.35
May 3.4	12	12	71 32 55.90	14	00	71 32 54.76
5.4	12	22	71 32 56.17	14	07	71 32 55.88
8.4	12	26	71 32 56.78	14	09	71 32 55.93
24.4	12	48	71 32 58.92	14	03	71 32 57.42
28.3	12	24	71 32 57.51	14	21	71 32 56.87
June 2.3	12	26	71 32 57.78	14	06	71 32 56.86
July 6.2	12	18	71 32 57.16	14	15	71 32 57.50
11.2	12	31	71 32 58.25	14	15	71 32 57.70
12.2	12	40	71 32 58.82	14	09	71 32 57.95
22.2	12	15	71 32 58.65	13	12	71 32 58.34
August 2.2	12	17	71 32 58.04	14	06	71 32 57.54
7.2	12	16	71 32 57.22	14	02	71 32 57.34
12.2	12	17	71 32 57.22	14	13	71 32 56.52
September 3.1	12	27	71 32 58.12	14	12	71 32 57.54
4.1	12	24	71 32 57.17	14	14	71 32 57.23
9.1	12	19	71 32 56.53	14	11	71 32 56.70
11.1	12	01	71 32 56.66	14	15	71 32 56.36
13.1	12	02	71 32 57.24	14	00	71 32 57.26
16.1	12	00	71 32 57.98	14	11	71 32 57.73
1898.						
August 1.7	0	15	71° 33′ 5.98″	2	18	71° 33′ 5.04″
14.7	0	12	71 33 6.00	2	13	71 33 5.86
20.6	0	10	71 33 5.90	2	20	71 33 4.88
October 15.5	0	26	71 32 59.87	2	26	71 33 0.35
November 2.4	0	26	71 33 4.56	2	21	71 33 4.48
3.4	0	30	71 33 4.52	2	19	71 33 4.54
19.4	0	24	71 33 5.08	2	17	71 33 4.78
27.3	0	18	71 33 0.71	2	27	71 32 59.85
December 18.3	0	17	71 33 10.10	2	16	71 33 9.96
24.3	0	31	71 32 57.53	2	07	71 32 58.05
27.3	0	27	71 32 59.55	2	16	71 32 58.07
1899.						
January 1.3	0	16	71 32 55.36	2	23	71 32 55.22
7.2	0	34	71 32 57.49	2	37	71 32 57.60
10.2	0	34	71 32 59.21	2	18	71 32 59.00
19.2	0	18	71 32 59.58	2	20	71 32 59.98
29.2	0	39	71 32 57.37	2	22	71 32 57.07

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OBSERVATIONS OF POLARIS. CLAMP EAST. NADIRS.

Date.		Sid. T. H.	M.	Nadirs.	Sid. T. H.	M.	Nadirs.
	1899.						
July	17.7	0	18	71° 32′ 58.20″	2	20	71° 32′ 58.70″
	21.7	0	09	71 32 58.09	2	12	71 32 58.20
	31.7	0	14	71 32 56.82	2	14	71 32 57.24
August	1.7	0	28	71 32 57.70	2	16	71 32 57.58
	5.7	0	21	71 32 56.96	2	16	71 32 56.60
	6.7	0	21	71 32 56 84	2	14	71 32 56.87
September	2.6	0	01	71 32 57.58	2	19	71 32 58.06
	12.6	0	22	71 32 57.17	2	14	71 32 56.76
	14.5	0	36	71 32 56.96	2	12	71 32 57.78
	1898.						
May	13.4	12	26	71° 33′ 5.26″	14	12	71° 33′ 4.60″
	17.4	12	15	71 33 6.20	14	16	71 33 5.19
December	27.8	12	16	71 32 57.14	14	26	71 32 57.86
	31.8	12	12	71 32 58.61	14	29	71 32 58.69
	1899.						
January	2.8	12	14	71 32 59.04	14	13	71 32 59.22
	15.7	12	12	71 32 58.71	14	16	71 32 58.08
	18.7	12	40	71 32 57.98	14	17	71 32 56.86
	21.7	12	17	71 33 3.41	14	16	71 33 3.06
February	16.7	12	27	71 32 56.96	14	22	71 32 57.12
	28.6	12	00	71 32 58.78	14	15	71 32 58.58
April	3.5	12	18	71 32 59.92	14	18	71 32 59.22
	4.5	12	20	71 33 0 04	14	20	71 33 0.09
	13.5	12	40	71 33 1.56	14	08	71 33 1.36
	14.5	12	30	71 33 0.94	14	15	71 33 0.62
	17.4	12	39	71 32 56.72	14	04	71 32 56.40
	26.4	12	10	71 32 58.20	14	15	71 32 58.12
	28.4	12	26	71 32 56.75	14	34	71 32 56.36
May	8.4	12	24	71 32 56.78	14	09	71 32 55.93
	28.3	12	24	71 32 57.51	14	21	71 32 56.87
June	26.3	12	38	71 32 58.24	14	09	71 32 58.54
	27.3	12	49	71 32 58.58	14	03	71 32 58.54
	29.3	12	36	71 32 58.12	14	16	71 32 58.20
	30.3	12	20	71 32 58.74	14	13	71 32 58.54
July	1.3	12	30	71 33 0.32	14	14	71 33 0.36

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OBSERVATIONS OF POLARIS. CLAMP WEST. NADIRS.

Date.		Sid. T. H.	M.	Nadirs.	Sid. T. H.	M.	Nadirs.
	1899.						
June	10.8	0	20	71° 33′ 2.82″	2	11	71° 33′ 3.43″
	15.8	0	13	71 32 57.93	2	04	71 32 58.25
	16.8	0	00	71 33 0.10	2	09	71 32 59.92
October	5.5	0	30	71 32 56.06	2	22	71 32 55.56
	9.5	0	31	71 32 58.80	2	07	71 32 58.64
	22.4	0	16	71 33 2.22	2	15	71 33 3.14
	23.4	0	35	71 32 52.46	2	10	71 32 52.48
November	26.3	0	05	71 33 3.20	2	58	71 33 2.89
December	17.3	0	27	71 32 43.36	2	12	71 32 43.91
	19.3	0	35	71 32 40.97	2	04	71 32 40.62
	26.3	0	26	71 32 43.16	2	10	71 32 41.55
	1900.						
January	21.3	0	40	71 32 46.06	2	18	71 32 45.64
	22.2	0	37	71 32 46.50	2	08	71 32 46.10
	24.2	0	34	71 32 46.26	2	05	71 32 46.11
	29.2	0	26	71 33 47.48	2	32	71 32 48.10
February	1.2	0	35	71 32 51.68	2	30	71 32 51.58
	9.2	0	22	71 32 53.70	2	46	71 32 52.74
	10.2	0	42	71 32 53.22	2	33	71 32 54.06
	11.2	0	20	71 32 55.84	2	00	71 32 55.43
	19.1	0	16	71 33 7.49	2	29	71 33 7.72
March	2.1	0	39	71 32 52.28	2	30	71 32 53.72
	3.1	0	51	71 32 53.52	2	07	71 32 53.76
	23.0	0	00	71 32 54.06	2	05	71 32 54.08
	24.0	0	28	71 32 55.44	2	06	71 32 56.04
	31.0	0	21	71 32 54.44	2	52	71 32 56.23
April	1.0	0	27	71 32 54.78	2	57	71 32 56.03
	4.0	0	26	71 32 50.06	2	36	71 32 49.85
	7.0	0	29	71 32 52.14	2	15	71 32 51.76
	18.9	0	32	71 32 57.00	2	37	71 32 57.92
	25.9	0	32	71 32 57.06	2	12	71 32 58.44
	28.9	0	42	71 32 51.95	2	11	71 32 52.90
	30.9	0	30	71 32 51.84	2	16	71 32 52.18
May	4.9	0	51	71 32 53.34	2	08	71 32 54.39
	20.8	0	34	71 32 45.34	2	12	71 32 46.06
June	12.8	0	50	71 32 48.87	2	08	71 32 49.44
	14.8	0	37	71 32 48.02	2	51	71 32 49.53
	15.8	0	46	71 32 45.90	2	06	71 32 46.80
	17.8	0	25	71 32 49.77	2	17	71 32 50.41
	19 8	0	28	71 32 50.97	2	57	71 32 51.19
July	11.7	0	19	71 32 50.56	2	60	71 32 50.26
	12.7	0	33	71 32 51.01	2	37	71 32 50.71
	15.7	0	41	71 32 53.25	2	16	71 32 53.19
	21.7	0	38	71 32 51.94	2	08	71 32 51.89
	25.7	0	40	71 32 53.23	2	27	71 32 51.27
August	3.7	0	28	71 32 52.08	2	34	71 32 51.57
	5.7	0	23	71 32 57.29	2	14	71 32 57.10
	6.7	0	24	71 32 51.48	2	30	71 32 50.64
	14.7	0	48	71 32 52.16	2	22	71 32 52.04
	15.7	0	43	71 32 52.31	2	08	71 32 51.57
	18.6	0	33	71 32 51.68	2	08	71 32 51.67
	31.6	0	31	71 32 52.70	2	10	71 32 51.80
September	21.6	0	25	71 32 53.38	2	32	71 32 52.92
	27.5	0	29	71 32 53.38	2	30	71 32 52.70
	29.5	0	30	71 32 54.30	2	29	71 32 53.76
October	3.5	0	20	71 32 54.94	2	13	71 32 54.52
	9.5	0	24	71 32 52.04	2	43	71 32 51.97
	12.5	0	33	71 32 54.58	2	19	71 32 54.12
	19.4	0	34	71 32 56.97	2	50	71 32 56.66
November	26.4	0	22	71 32 48.64	2	15	71 32 48.81
December	2.3	0	55	71 32 49.13	2	05	71 32 49.10
	13.3	0	34	71 32 49.60	2	30	71 32 48.50

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OBSERVATIONS OF POLARIS. CLAMP WEST. NADIRS.

Date.		Sid. T. H.	Sid. T. M.	Nadirs.			Sid. T. H.	Sid. T. M.	Nadirs.		
	1901.										
January	20.2	0	31	71°	32	53.44″	2	15	71°	32′	54.46″
	30.2	0	27	71	32	51.30	2	40	71	32	51.08
February	7.2	0	28	71	32	57.76	2	25	71	32	57.81
	1899.										
June	12.3	12	20	71°	33′	1.84″	14	11	71°	33′	1.54′
	16.3	12	31	71	32	59.88	14	09	71	33	0.14
	23.3	12	31	71	32	59.86	14	17	71	32	59.64
October	11.9	12	20	71	32	58.22	14	14	71	32	58.22
	17.9	15	24	71	33	0.14	14	15	71	33	0.20
	20.9	12	14	71	33	01.03	14	05	71	33	01.80
	23.9	12	31	71	32	52.18	14	09	71	32	52.89
	24.9	12	29	71	32	51.56	14	14	71	32	52.88
November	29.8	12	48	71	32	50.12	14	14	71	32	50.34
December	5.8	12	32	71	32	47.72	14	30	71	32	48.16
	7.8	12	30	71	32	47.12	14	11	71	32	47.66
	19.8	12	23	71	32	40.03	14	10	71	32	40.04
	20.8	12	14	71	32	40.31	14	10	71	32	40.32
	1900.										
January	21.7	12	22	71	32	45.37	14	11	71	32	45.06
	22.7	12	20	71	32	45.50	14	11	71	32	45.34
	27.7	12	40	71	32	48.46	14	22	71	32	48.11
	28.7	12	20	71	32	44.24	14	34	71	32	44.05
	30.7	12	24	71	32	49.24	14	41	71	32	48.36
February	9.6	12	21	71	32	51.84	14	12	71	32	51.68
	10.6	12	26	71	32	52.90	14	14	71	32	53.15
	13.6	12	33	71	32	52.48	14	14	71	32	52.53
	17.6	12	16	71	33	06.55	14	39	71	33	06.76
March	1.6	12	28	71	32	51.26	14	44	71	32	50.81
	2.6	12	32	71	32	52.92	14	29	71	32	52.18
	19.6	12	43	71	32	53.56	14	07	71	32	53.22
	23.5	12	20	71	32	54.48	14	03	71	32	53.48
	30.5	12	31	71	32	56.20	14	03	71	32	55.41
	31.5	12	49	71	32	54.46	14	09	71	32	54.31
April	3.5	12	24	71	32	49.06	14	14	71	32	49.75
	9.5	12	19	71	32	50.30	14	15	71	32	49.94
	10.5	12	46	71	32	50.90	14	05	71	32	50.70
	25.4	12	37	71	32	57.34	14	13	71	32	56.50
	27.4	12	26	71	32	57.92	14	13	71	32	58.14
	30.4	12	43	71	32	51.74	14	13	71	32	51.40
May	6.4	12	48	71	32	53.18	14	13	71	32	53 32
	26.3	12	45	71	32	53.07	14	25	71	32	52.72
June	12.3	12	32	71	32	49.50	14	13	71	32	49.18
	18.3	12	47	71	32	52.00	14	15	71	32	51.61
	28.3	12	40	71	32	50.07	14	06	71	32	49.54
July	4.2	12	10	71	32	51.54	14	54	71	32	50.78
	5.2	12	21	71	32	50.13	14	11	71	32	50.18
	9.2	12	48	71	32	50.12	14	51	71	32	50.08
	13.2	12	38	71	32	51.80	14	60	71	32	52.16
	21.2	12	38	71	32	52.68	14	51	71	32	52.39
	28.2	12	47	71	32	52.40	14	13	71	32	52.34
August	7.2	12	55	71	32	48.22	14	04	71	32	48.46
	10.2	12	40	71	32	48.76	14	08	71	32	48.88
	24.1	12	27	71	32	52.98	14	11	71	32	53.02
	29.1	12	42	71	32	53.60	14	17	71	32	53.90
September	6.1	12	35	71	32	48.74	14	30	71	32	49.00
	12.1	12	25	71	32	49.66	14	35	71	32	49.96
	14.1	12	48	71	32	53.21	14	11	71	32	53.16
	30.0	12	19	71	32	54.76	14	47	71	32	54.74

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OBSERVATIONS OF POLARIS. CLAMP WEST. NADIRS.

Date.		Sid. T. H.	Sid. T. M.	Nadirs.	Sid. T. H.	Sid. T. M.	Nadirs.
	1900.						
October	14.0	12	26	71° 32′ 55.46″	14	18	71° 32′ 56.59″
	16.9	12	07	71 32 55.78	14	15	71 32 56.76
	27.9	12	30	71 32 49.90	14	08	71 32 50.34
	30.9	12	34	71 32 49.83	14	25	71 32 50.07
November	3.9	12	24	71 32 49.80	14	07	71 32 50.53
December	1.8	12	27	71 32 49.12	14	21	71 32 49.07
	2.8	12	42	71 32 48.82	14	17	71 32 49.30
	21.8	12	37	71 32 48.11	14	45	71 32 48.14
	1901.						
February	10.6	12	30	71 32 59.97	14	32	71 32 59.53
	14.6	12	32	71 32 59.86	14	36	71 32 58.58
	1899.						
June	18.8	0	16	71° 33′ 1.00″	2	19	71° 33′ 0.70″
	20.8	0	20	71 32 59.14	2	12	71 32 59.50
	24.8	0	26	71 32 59.32	2	16	71 32 59.68
October	12.5	0	26	71 32 58.37	2	15	71 32 58.25
	15.5	0	14	71 33 0.65	2	05	71 33 0.30
	31.4	0	00	71 32 52.15	2	20	71 32 51.73
December	1.3	0	31	71 32 47.29	2	18	71 32 46.38
	4.3	0	26	71 32 45.72	2	00	71 32 45.96
	21.3	0	40	71 32 46.08	2	18	71 32 45.64
	1900.						
June	22.8	0	47	71 32 50.72	2	17	71 32 50.64
	25.8	0	35	71 32 51.02	2	22	71 32 50.94
	27.8	0	18	71 32 50.29	2	30	71 32 49.72
July	22.8	0	28	71 32 53.58	2	17	71 32 53.34
August	25.6	0	20	71 32 53.07	2	23	71 32 52.38
	27.6	0	24	71 32 52.63	2	21	71 32 52.74
	30.6	0	30	71 32 52.48	2	23	71 32 52.02
September	3.6	0	34	71 32 47.74	2	15	71 32 47.78
	25.5	0	18	71 32 53.56	2	22	71 32 53.58
October	5.5	0	16	71 32 54.38	2	18	71 32 54.23
	14.5	0	26	71 32 54.77	2	25	71 32 54.48
	17.5	0	22	71 32 56.36	2	09	71 32 56.40
	20.4	0	25	71 32 50.28	2	09	71 32 50.13
December	10.3	0	30	71 32 49.64	2	00	71 32 49.89
	15.3	0	34	71 32 50.57	2	20	71 32 50.68
	1901.						
January	22.2	0	33	71 32 51.46	2	07	71 32 51.16
February	10.1	0	22	71 32 58.08	2	30	71 32 58.38
	1899.						
June	11.3	12	25	71° 33′ 5.52″	14	10	71° 33′ 5.49″
	13.3	12	26	71 33 1.04	14	08	71 33 0.52
	17.3	12	25	71 33 1.01	14	08	71 33 0.49
December	21.8	12	16	71 32 40.35	14	16	71 32 40.00
	1900.						
February	2.6	12	21	71 32 51.90	14	30	71 32 51.25
	15.6	12	12	71 32 55.80	14	18	71 32 55.48
	25.6	12	31	71 32 50.06	14	30	71 32 49.66
March	11.6	12	22	71 32 49.67	14	24	71 32 50.73
	26.5	12	31	71 32 55.90	14	08	71 32 55.53

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OBSERVATIONS OF POLARIS. CLAMP WEST. NADIRS.

Date.		Sid. T. H.	Sid. T. M.	Nadirs.	Sid. T. H.	Sid. T. M.	Nadirs.
	1900.						
April	4.5	12	20	71° 32′ 49.23″	14	14	71° 32′ 49.32″
	9.5	12	19	71 32 50.30	14	15	71 32 49.94
	14.5	12	46	71 32 56.46	14	13	71 32 57.08
	22.4	12	45	71 32 56.46	14	14	71 32 56.38
May	4.4	12	50	71 32 53.88	14	14	71 32 53.18
	30.3	12	36	71 32 53.71	14	26	71 32 53.58
June	3.3	12	30	71 32 53.46	14	40	71 32 53.22
	12.3	12	32	71 32 49.50	14	13	71 32 49.18
	17.3	12	26	71 32 52.92	14	17	71 32 52.52
	18.3	12	47	71 32 52.00	14	15	71 32 51.51
	19.3	12	36	71 32 51.86	14	11	71 32 52.26
	25.3	12	41	71 32 50.83	14	16	71 32 51.35
July	15.2	12	22	71 32 55.70	14	19	71 32 54.26
	18.3	12	44	71 32 52.28	14	11	71 32 52.27
	25.2	12	31	71 32 54.11	14	21	71 32 53.37
	26.2	12	33	71 32 53.72	14	12	71 32 53.75
December	11.8	12	40	71 32 49.66	14	39	71 32 49.76
	15.8	12	22	71 32 48.24	14	50	71 32 49.00
	1901.						
January	30.7	12	42	71 32 52.20	14	58	71 32 51.39
February	7.6	12	27	71 32 56.53	14	26	71 32 56.66

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OBSERVATIONS OF POLARIS. CLAMP EAST.

No.	Date.	I.	S.	App. Z.	Red. 1900.0.	1900.0 Z.	Run.	Per. error.
	1898.							
1	April 25.9	3	3	46° 29′ 3.34″	+31.03″	34.37″	−0.17″	+0.07″
2	26.9	3	3	46 29 3.15	+31.29	34.44	−0.14	+0.04
3	May 5.9	3	3	46 29 0.25	+33.84	34.09	−0.09	+0.06
4	8.9	3-4	3	46 28 59.38	+34.54	33.90	−0.13	+0.05
5	16.9	3	3	46 28 57.68	+36.35	34.03	−0.15	+0.03
6	24.9	3	3	46 28 56.19	+37.87	34.06	+0.04	+0.04
7	25.9	2-3	2-3	46 28 56.10	+38.03	34.13	+0.08	+0.06
8	26.9	3	3	46 28 56.11	+38.21	34.32	+0.03	+0.10
9	30.8	3	3	46 28 54.71	+38.96	33.67	+0.03	+0.10
10	June 2.8	3	3	46 28 55.06	+39.42	34.48	+0.03	+0.03
11	6.8	3	3	46 28 54.88	+39.78	34.66	+0.06	+0.01
12	16.8	3	3-4	46 28 54.16	+40.77	34.93	+0 02	+0.01
13	19.8	3	3	46 28 53.06	+40.86	33.92	+0.03	+0.01
14	20.8	3	3	46 28 52.52	+40.88	33.40	+0.02	+0.00
15	22.8	3	3	46 28 53.43	+40.92	34.35	+0.03	−0.01
16	July 5.8	2-3	3	46 28 53.89	+40.79	34.68	−0.02	+0.07
17	7.8	3	3	46 28 53.38	+40.70	34.08	+0 03	+0.04
18	10.7	3-2	3-2	46 28 52.47	+40.61	33.08	+0.02	+0.02
19	13.7	3	3	46 28 54.23	+40.44	34.67	+0.02	+0.00
20	20.7	3	3	46 28 55.12	+39.59	34.71	+0.05	+0.06
21	21.7	3	3	46 28 54.10	+39.48	33.58	+0.02	+0.05
22	22.7	3	3	46 28 55 03	+39.38	34.41	+0.03	+0.04
23	25.7	3-4	3	46 28 55.12	+39.06	34.18	+0.03	+0.05
24	26.7	.....	.....	46 28 55.42	+38.92	34.34	+0.02	+0.06
25	August 4.7	3-4	3	46 28 57.24	+37.18	34.42	+0.04	+0.05
26	9.7	4	3	46 28 59.53	+36.27	35.80	+0.04	+0.07
27	13.7	3	3	46 28 58.66	+35.28	33.94	+0.00	+0.08
28	19.7	3	3-2	46 29 01.44	+33.83	35.27	+0.04	+0.06
29	25.6	3	3	46 29 02.38	+32.21	34.59	+0.03	−0.03
30	26.6	3	3-2	46 29 02.23	+31.89	34.12	+0.04	+0.03
31	September 24.5	3	2	46 29 12.44	+22.27	34.71	+0.07	−0.07
32	26.5	.....	.....	46 29 14.25	+21.51	35.76	+0.05	−0.03
33	28.5	3	2	46 29 14.96	+20.80	35.76	+0.08	−0.06
34	October 8.5	3	3	46 29 16.78	+17.07	33.85	+0.08	−0.05
35	11.5	3	3	46 29 19.54	+15.94	35.48	+0.08	−0.10
36	27.4	3	3	46 29 25.01	+09.88	34.89	+0.10	−0.11
37	31.4	3	3	46 29 26.01	+08.47	34.48	+0.09	−0.08
38	November 7.4	3	3	46 29 29.56	+05.81	35.37	+0.09	−0.10
39	12.4	3	3	46 29 30.88	+04.19	35.07	+0.11	−0.11
40	13.4	3	3	46 29 31.36	+03.85	35.21	+0.10	−0.11
41	26.3	.....	.....	46 29 35.00	−0.41	34.59	+0.10	−0.10
42	December 10.3	3	3	46 29 39.69	−04.17	35.52	+0.13	−0.08
43	13.3	3	3	46 29 39.62	−04.93	34.69	+0.13	−0.03
44	15.3	2-3	2-3	46 29 41.11	−05.45	35.66	+0.13	−0.02
45	17.3	3	2-3	46 29 41.19	−05.91	35.28	+0.13	+0.01
46	31.3	3-4	4-3	46 29 42.50	−08.15	34.35	+0.11	−0.10
	1899.							
47	January 2.3	2-3	2-3	46 29 43.51	−08.33	35.18	+0.15	−0.06
48	9.2	3	2	46 29 43.73	−08.85	34.88	+0.13	−0.04
49	14.2	3	2-3	46 29 43.57	−09.21	34.36	+0.12	−0.08
50	21.2	2-3	2-3	46 29 44.05	−09.10	34.95	+0.14	−0.08
51	24.2	3	3	46 29 43.19	−09.09	34.10	+0.13	−0.06
52	31.2	3	3	46 29 42.84	−08.61	34.23	+0.09	−0.10
53	February 8.2	3	3	46 29 41.60	−07.83	33.77	+0.14	−0.08
54	13.2	3	3	46 29 41.65	−07.08	34.57	+0.12	−0.05
55	16.2	.....	.....	46 29 41.73	−06.49	35.24	+0.11	−0.09
56	24.1	3	3	46 29 39.39	−05.03	34.36	+0.09	−0.01
57	March 1.1	4-3	4-3	46 29 38.03	−03.72	34.31	+0.11	−0.04
58	April 4.0	3	3	46 29 28 50	+05.92	34.42	+0.11	−0.11
59	9.0	3	3	46 29 26.53	+07.52	34.05	+0.10	−0.07
60	18.9	3-4	4	46 29 24.08	+10.57	34.65	+0.07	−0.14
61	20.9	.....	.....	46 29 23.31	+11.19	34.50	+0.10	−0.12
62	23.9	3	3	46 29 22.53	+12.18	34.71	+0.10	−0.14
63	25.9	3-4	3	46 29 20.70	+12.80	33.50	+0.10	−0.10
64	27.9	3	3	46 29 21.90	+13.34	35.24	+0.10	−0.15
65	28.9	2	3	46 29 21.21	+13.59	34.80	+0.10	−0.13

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OBSERVATIONS OF POLARIS. CLAMP EAST.

No.	Date.	I.	S.	App. Z.	Red. 1900 0.	1900.0 Z.	Run.	Per. error.
	1899.							
66	May 8.9	3	3	46° 29′ 17.97″	+16.25″	34.22″	+0.07″	−0.15″
67	10.9	4	3	46 29 17.52	+16.74	34.26	+0.09	−0.12
68	23.8	3	3	46 29 15.10	+19.60	34.70	+0.07	−0.09
69	24.8	3	3	46 29 14.73	+19.77	34.50	+0.07	−0.12
70	June 1.8	2-3	2-3	46 29 13.60	+20.94	34.54	+0.08	+0.04
71	3.8	3	3	46 29 13.24	+21.28	34.52	+0.08	−0.11
72	4.8	3	3	46 29 13.73	+21.44	35.17	+0.08	−0.10
73	29.7	3-4	3	46 29 11.40	+22.94	34.34	+0.05	−0.05
74	July 8.7	4	3	46 29 11.35	+22.62	33.97	+0.06	−0.08
75	10.7	2	2	46 29 12.12	+22.50	34.62	+0.08	−0.12
76	18.7	3	3	46 29 12.72	+21.95	34.67	+0.06	−0.08
77	22.7	3	3	46 29 13.77	+21.34	35.11	+0.05	−0.05
78	August 10.7	3-4	3	46 29 16.74	+18.12	34 86	+0.06	−0.12
79	12.7	4-3	3	46 29 16.23	+17.73	33.96	+0.09	−0.13
80	13.7	3-4	3	46 29 16.06	+17.51	33.57	+0.07	−0.14
81	September 1.6	3	2	46 29 22.26	+12.21	34.47	+0.09	−0.11
82	11.6	3-4	3	46 29 26.03	+09.18	35.21	+0.11	−0.09
83	13.5	4	3	46 29 25.68	+08.43	34.11	+0.10	−0.11
84	26.5	4	3	46 29 30.33	+03.84	34.17	+0.11	−0.11
85	30.5	4	3-4	46 29 31.89	+02.30	34.19	+0.11	−0.12
86	October 2.5	2-3	2-3	46 29 33.32	+01.61	34.93	+0.12	−0.10

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OBSERVATIONS OF POLARIS. CLAMP EAST. S. P.

No.	Date.	I.	S.	App. Z. s. p.	Red 1900.0.	Z 1900.0.	Run.	Per. error.
	1898.							
1	April 26.4	.....	.....	48° 57′ 12.94″	−31.16″	56′ 41.78″	−0.18″	−0.01″
2	27.4	2-3	3	48 57 12.46	−31.42	56 41.04	- 0.08	−0.01
3	May 5.4	3-4	2	48 57 15.46	−33.73	56 41.73	−0.12	−0.00
4	7.4	3	3	48 57 16.02	−34.20	56 41.82	−0.15	+0.01
5	9.4	2	2	48 57 15.95	−34.62	56 41.33	−0.11	+0.01
6	23.4	2-3	2-3	48 57 20.25	−37.64	56 42.61	+0.01	+0.04
7	25.4	2-3	2	48 57 19.74	−37.95	56 41.79	+0.02	+0.02
8	30.3	3	3	48 57 20.53	−38.86	56 41.67	+0.01	+0.07
9	June 1.3	2-3	2	48 57 20.73	−39.21	56 41.52	+0.01	+0.03
10	3.3	2-3	2	48 57 21.72	−39.47	56 42 25	+0.00	+0.03
11	14.3	2-3	3	48 57 21.87	−40.57	56 41.30	+0.05	+0.02
12	17.3	3	2	48 57 22.79	−40.79	56 42.00	+0.01	−0.01
13	21.3	3	2-3	48 57 22.74	−40.89	56 41.85	+0.01	−0.02
14	22.3	3	3	48 57 23.51	−40.91	56 42.60	+0.01	−0.01
15	July 6.2	2	3	48 57 23.59	−40.76	56 41.83	+0.03	+0.05
16	9.2	2 3	2-3	48 57 21.85	−40.66	56 41.19	+0.02	+0.04
17	11.2	2-3	2 3	48 57 22.49	−40.59	56 41.90	+0.01	+0.03
18	12.2	3-2	3-2	48 57 22.76	−40.55	56 42.21	+0.01	+0.02
19	14.2	3	3	48 57 21.72	−40.39	56 41.33	+0.01	+0.00
20	21.2	3	3	48 57 21.13	−39.54	56 41.59	+0.02	+0.04
21	22.2	3	3	48 57 20.93	−39.43	56 41.50	+0.02	+0.05
22	29.2	3	3	48 57 19.45	−38.47	56 40.98	+0.02	+0.03
23	August 2.2	3	3	48 57 18.85	−37.63	56 41.22	+0.01	+0.07
24	4.2	3-4	3-4	48 57 18.47	−37.26	56 41.21	+0.01	+0.04
25	10.2	3-4	3-4	48 57 17.16	- 36.16	56 41.00	+0.02	+0.10
26	25.1	3	3	48 57 13.40	−32 38	56 41.02	+0.00	−0.02
27	26.1	2	2-3	48 57 13.35	−32.05	56 41.30	−0.01	+0.06
28	27.1	2	3	48 57 13.07	−31.72	56 41.35	+0.01	+0.04
29	September 25.0	3	2	48 57 04.10	−22.07	56 42.03	−0.04	−0.06
30	27.0	.....	.....	48 57 02.71	−21.33	56 41.38	−0.03	−0.05
31	29.0	.....	.....	48 57 02.08	−20.63	56 41.45	−0.09	- 0.02
32	October 9.0	3-4	3	48 56 57.77	−16 88	56 40.89	- 0.05	−0.08
33	14.9	3-4	3	48 56 55.96	−14.72	56 41.24	−0.06	−0.07
34	24.9	3	3	48 56 53.08	−10.75	56 42.33	−0.12	−0.11
35	26.9	3	3	48 56 50.52	−10.05	56 40.47	−0.07	−0.10
36	November 2.9	2-3	2-3	48 56 49.62	−07.49	56 42.13	−0.06	−0.05
37	15.9	3	3	48 56 44.63	−02.92	56 41.71	−0.11	−0.05
38	24.8	2-3	2-3	48 56 41.27	−00.02	56 41.25	−0.11	−0.01
39	December 12.8	3-4	3-4	48 56 35.73	+04.80	56 40.53	−0.14	+0.03
40	13.8	3	3	48 56 36.90	+05.06	56 41.96	−0.13	+0.02
41	15.8	3	3	48 56 36.78	+05.57	56 42.35	−0.12	+0.09
42	28.8	3	3	48 56 34.87	+07.81	56 42.68	−0.12	−0.01
	1899.							
43	January 6.8	.....	.....	48 56 31.83	+08.62	56 40.45	−0.13	−0.09
44	9.7	3-4	3	48 56 32.65	+08.90	56 41.55	−0.11	−0.02
45	14.7	2	2	48 56 32.86	+09.22	56 42.08	−0.09	−0.11
46	26.7	4	3	48 56 31.99	+09.02	56 41.01	- 0.03	−0.08
47	31.7	4	3	48 56 33.31	+08.55	56 41.86	−0.14	−0.07
48	February 6.7	4-3	3	48 56 32.78	+07.97	56 40.75	−0.13	+0.01
49	13.7	3-2	3	48 56 34.83	+06.99	56 41.82	−0.13	- 0.09
50	24.6	2-3	2-3	48 56 37.11	+04.91	56 42.02	−0.13	−0.08
51	27.6	4	4	48 56 38.30	+04.13	56 42.43	−0.13	−0.01
52	March 23.5	3-4	3-4	48 56 44.09	−02.35	56 41.74	−0.08	−0.19
53	April 8.5	3	3	48 56 49.96	−07.35	56 42.61	−0.08	−0.05
54	9.5	3	2	48 56 50.19	−07.69	56 42.50	−0.08	−0.13
55	10.5	3	3	48 56 49.97	−08.04	56 41.93	−0.04	−0.16
56	20.4	3-4	3	48 56 53.62	−11.03	56 42.59	−0.07	−0.13
57	22.4	3	3	48 56 53.25	−11.69	56 41.56	−0.09	−0.12
58	25.4	2-3	2	48 56 54.81	- 12.66	56 42.15	−0.05	−0.09
59	May 3.4	2-3	2-3	48 56 57.25	- 14.70	56 42.55	−0.03	+0.04
60	5.4	3	2	48 56 57.32	−15.26	56 42.06	−0 05	−0.14
61	8.4	2-3	2	48 56 57.93	- 16.11	56 41.82	−0.08	−0.17
62	24.4	.....	.....	48 57 02.07	- 19.69	56 42.38	−0.03	−0.11
63	28.3	3	3	48 57 02.67	−20.25	56 42.42	−0.06	−0.16

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OBSERVATIONS OF POLARIS. CLAMP EAST. S. P.

No.	Date.	I.	S.	App. Z. s. p.	Red. 1900.0.	Z. 1900.0.	Run.	Per. error.
	1899.							
64	June 2.3	3	3	48° 57′ 04.20″	−21.03″	56′ 43.17″	−0.03″	−0.06″
65	July 6.2	2	2-3	48 57 05.12	−22.82	56 42.30	−0.05	−0.16
66	11.2	2	2-3	48 57 05.00	−22.47	56 42.53	−0.03	−0.09
67	12.2	2-3	2-3	48 57 05.05	−22.43	56 42.62	−0.03	−0.08
68	22.2	2	3	48 57 02.83	−21.42	56 41.41	−0.02	−0.06
69	August 2.2	3-4	3-4	48 57 00.88	−19.79	56 41.09	−0.02	−0.06
70	7.2	2-3	2-3	48 57 00.16	−18.75	56 41.41	−0.01	−0.08
71	12.2	3	3	48 56 59.29	−17.84	56 41.45	−0.04	−0.10
72	September 3.1	3-4	3	48 56 53.01	−11.74	56 41.27	−0.06	−0.12
73	4.1	3	3	48 56 52.53	−11.45	56 41.08	−0.06	−0.14
74	9.1	3	3	48 56 51.50	−10.03	56 41.47	−0.06	−0.14
75	11.1	3	3	48 56 50.66	−09.36	56 41.30	−0.04	−0.14
76	13.1	3	3 4	48 56 49.38	−08.62	56 40.76	−0.04	−0.13
77	16.1	4	3	48 56 49.85	−07.50	56 42.35	−0.07	−0.13

OBSERVATIONS OF POLARIS. CLAMP EAST. R.

No.	Date.	I.	S.	App. Z. R.	Red. 1900.0.	Z. 1900.0.	Run.	Per. error.
	1898.							
1	August 1.7	3	3	133° 30′ 60.53″	−37.73″	22.80″	−0.03″	−0.04″
2	14.7	2-3	3	133 30 57.12	−35.02	22.10	−0.04	−0.03
3	20.6	3	3	133 30 55.67	−33.60	22.07	−0.06	−0.04
4	October 15.5	3	3	133 30 37.82	−14.54	23.28	−0.09	−0.06
5	November 2.4	.....	.....	133 30 30.03	−07.68	22.35	−0.11	+0.02
6	3.4	.....	.....	133 30 29.59	−07.29	22.30	−0.10	+0.01
7	19.4	3	3	133 30 24.99	−01.65	23.34	−0.13	+0.02
8	27.3	3	3	133 30 21.55	+00.71	22.26	−0.13	−0.05
9	December 18.3	2-3	2-3	133 30 15.48	+06.11	21.59	−0.16	+0.06
10	24.3	2-3	2-3	133 30 15.11	+07.04	22.15	−0.13	+0.01
11	27.3	3-4	3-4	133 30 14.23	+07.55	21.78	−0.15	−0.02
	1899.							
12	January 1.3	.....	.....	133 30 12.92	+08.25	21.17	−0.13	−0.07
13	7.2	3	3	133 30 13.65	+08.66	22.31	−0.14	−0.05
14	10.2	3-2	3	133 30 12.92	+08.94	21.76	−0.15	−0.06
15	19.2	3	3	133 30 12.30	+09.14	21.44	−0.15	−0.03
16	29.2	3	3	133 30 13.31	+08.83	22.14	−0.13	−0.03
17	July 17.7	3	3	133 30 45.14	−22.08	23.06	−0.08	−0.11
18	21.7	4	3	133 30 43.80	−21.50	22.30	−0.08	−0.11
19	31.7	4	3-4	133 30 43.56	−20.09	23.47	−0.09	−0.10
20	August 1.7	3	2	133 30 42.22	−19.90	22.32	−0.08	−0.10
21	5.7	3-4	3	133 30 41.12	−19.05	22.07	−0.09	−0.12
22	6.7	4	3	133 30 41.64	−18.84	22.80	−0.07	−0.12
23	September 2.6	3	2	133 30 33.55	−11.90	21.65	−0.07	−0.07
24	12.6	.....	.....	133 30 32.34	−08.81	23.53	−0.10	−0.12
25	14.5	3	3	133 30 30.73	−08.05	22.68	−0.09	−0.12

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OBSERVATIONS OF POLARIS. CLAMP EAST. S. P. R.

No.	Date.	I.	S.	App. Z. s. p. R.	Red. 1900.0.	1900.0. Z.	Run.	Per. error.
	1898.							
1	May 13.4	2-3	2-3	131° 02' 38.89"	+35.46"	03' 14.35"	−0.33"	−0.01"
2	17.4	3	3	131 02 38.87	+36.47	03 14.84	−0.01	−0.00
3	December 27.8	.....	.....	131 03 22.39	−07.64	03 14.75	+0.12	−0.10
4	31.8	3.	3-2	131 03 22.74	−08.20	03 14.54	+0.11	−0.10
	1899.							
5	January 2.8	3	3	131 03 22.45	−08.36	03 14.09	+0.10	−0.11
6	15.7	3	3	131 03 23.63	−09.22	03 14.41	+0.12	−0.11
7	18.7	3	3	131 03 23.87	−09.16	03 14.71	+0.12	−0.11
8	21.7	3	3	131 03 23.70	−09.09	03 14.61	+0.13	−0.06
9	February 16.7	3	3	131 03 20.16	−06.40	03 13.76	+0.11	−0.14
10	28.6	3	3	131 03 18.74	−03.86	03 14.88	+0.12	−0.10
11	April 3.5	2	2	131 03 08.57	+05.78	03 14.35	+0.08	−0.10
12	4.5	2	2	131 03 08.39	+06.06	03 14.45	+0.08	−0.08
13	13.5	3	3	131 03 06.74	+09.01	03 14.75	+0.05	−0.04
14	14.5	3	3	131 03 06.01	+09.30	03 15.31	+0.05	−0.00
15	17.4	3	3	131 03 04.93	+10.12	03 15.05	+0.04	−0.01
16	26.4	.....	.....	131 03 01.89	+12.95	03 14.84	+0.08	−0.02
17	28.4	3	3	131 03 01.08	+13.47	03 14.55	+0.05	−0.09
18	May 8.4	2-3	2	131 02 58.39	+16.11	03 14.50	+0.02	+0.01
19	28.3	3	3	131 02 55.06	+20.25	03 15.31	+0.00	−0.00
20	June 26.3	2	2	131 02 51.71	+22.87	03 14.58	+0.02	−0.03
21	27.3	2-3	2	131 02 51.53	+22.88	03 14.41	−0.09	−0.01
22	29.3	2-3	2-3	131 02 52.02	+22.92	03 14.94	+0.03	−0.03
23	30.3	.....	.....	131 02 51.49	+22.95	03 14.44	+0 02	−0.03
24	July 1.3	.....	.....	131 02 50.56	+22.97	03 13.53	+0.00	−0.01

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OBSERVATIONS OF POLARIS. CLAMP WEST.

No.	Date.	I.	S.	App. Z.	Red. 1900.0.	1900.0. Z.	Run.	Per. error.
	1899.							
1	June 10.8	2-3	2-3	46° 29′ 17.89″	+22.03″	29′ 39.92″	+0.09	+0.00
2	15.8	3	3	46 29 16.42	+22.51	29 38.93	+0.06	+0.18
3	16.8	.....	.....	46 29 16.94	+22.62	29 39.56	+0.10	+0.18
4	October 5.5	4	3	46 29 38.57	+00.61	29 39.18	+0.13	+0.04
5	9.5	3	3	46 29 40.30	−00.92	29 39.38	+0.12	−0.02
6	23.4	3-4	3	46 29 45.58	−06.88	29 39.70	+0.14	−0.02
7	23.4	3	3	46 29 45.71	−06.28	29 39.43	+0.15	+0.03
8	November 26.3	3	2	46 29 57.30	−18.14	29 39.16	+0.18	+0.03
9	December 17.3	2	2	46 30 02.83	−23.47	29 39.36	+0.19	+0.02
10	19.3	3	3	46 30 02.39	−23.92	29 38.47	+0.16	−0.03
11	26.3	2-3	2-3	46 30 03.39	−24.97	29 38.42	+0.17	+0.02
	1900.							
12	January 21.3	2-3	2-3	46 30 06.27	−26.79	29 39.48	+0.22	+0.06
13	22.2	2-3	2	46 30 06.04	−26.72	29 39.32	+0.17	+0.06
14	24.2	3-4	3	46 30 06.02	−26.62	29 39.40	+0.18	+0.04
15	29.2	2-3	2-3	46 30 06.69	−26.48	29 40.21	+0.16	+0.09
16	February 1.2	2	2-3	46 30 05.87	−26.29	29 39.58	+0.19	+0.10
17	9.2	4	4	46 30 04.59	−25.28	29 39.31	+0.19	+0.10
18	10.2	3	3	46 30 05.09	−25.17	29 39.92	+0.19	+0.08
19	11.2	2	2	46 30 05.17	−25.06	29 40.11	+0.17	+0.07
20	19.1	4	3-4	46 30 02.96	−23.56	29 39.40	+0.17	+0.00
21	March 2.1	3	3	46 30 00.99	−21.26	29 39.73	+0.15	+0.06
22	3.1	3	3	46 30 00.08	−20.98	29 39.05	+0.16	+0.02
23	23.0	3-4	3-4	46 29 54.12	−15.33	29 38.79	+0.15	+0.02
24	24.0	4	4	46 29 54.23	−15.07	29 39.16	+0.15	+0.02
25	31.0	3 4	3	46 29 52.39	−12.88	29 39.51	+0.14	+0.03
26	April 1.0	3	3	46 29 51.97	−12.53	29 39.44	+0.14	+0.01
27	4.0	3-4	3-4	46 29 50.52	−11.58	29 38.94	+0.14	+0.03
28	7.0	3-4	3-4	46 29 50.65	−10.73	29 39.92	+0.16	+0.04
29	18.9	4	4	46 29 46.10	−06.88	29 39.24	+0.14	+0.01
30	25.9	2-4	3	46 29 44.93	−04.89	29 40.04	+0.14	+0.02
31	28.9	3-2	3-2	46 29 44.45	−03.94	29 40.51	+0.14	+0.02
32	30.9	3	2-3	46 29 42.86	−03.39	29 39.47	+0.13	+0.04
33	May 4.9	2	2	46 29 41.77	−02.43	29 39.34	+0.12	+0.02
34	20.8	.....	.....	46 29 37.83	+01.36	29 39.19	+0.11	−0.02
35	June 12.8	3	3	46 29 35.41	+04.92	29 40.33	+0.12	−0.04
36	14.8	3	3	46 29 34.98	+05.01	29 39.99	+0.10	−0.08
37	15.8	2	2-3	46 29 34.59	+05.06	29 39.65	+0.10	−0.03
38	17.8	2	2-3	46 29 34.48	+05.19	29 39.67	+0.11	−0.15
39	19.8	2-3	2-3	46 29 34.79	+05.35	29 40.14	+0.12	−0.16
40	July 11.7	3	3	46 29 33.78	+05.21	29 38.99	+0.12	−0.21
41	12.7	3	3	46 29 33.61	+05.11	29 38.72	+0.10	−0.21
42	15.7	3	3	46 29 34.15	+04.85	29 39.00	+0.12	−0.25
43	21.7	3-4	3-4	46 29 34.82	+04.34	29 39.16	+0.11	−0.21
44	25.7	3	3	46 29 34.56	+03.70	29 38.26	+0.12	−0.23
45	August 3.7	3	3	46 29 37.06	+02.40	29 39.46	+0.11	−0.36
46	5.7	3	1-2	46 29 37.83	+02.00	29 39.83	+0.14	−0.16
47	6.7	3	2	46 29 38.07	+01.78	29 39.85	+0.12	−0.26
48	14.7	4	4	46 29 39.08	+00.03	29 39.11	+0.12	−0.29
49	15.7	4	4	46 29 39.49	−00.18	29 39.31	+0.11	−0.30
50	18.6	.....	.....	46 29 40.56	−00.92	29 39.64	+0.13	−0.24
51	31.6	3 4	3	46 29 42.58	−04.42	29 38.16	+0.13	−0.24
52	September 21.6	4	3	46 29 50.43	−11.47	29 38.96	+0.15	−0.16
53	27.5	4	3	46 29 52.35	−13.44	29 38.91	+0.16	−0.18
54	29.5	3	3	46 29 54.28	−14.20	29 40.08	+0.16	−0.16

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OBSERVATIONS OF POLARIS. CLAMP WEST.

No.	Date.	I.	S.	App. Z.	Red. 1900.0.	1900.0. Z.	Run.	Per. error.
	1900.							
55	October 3.5	2-3	2	46° 29′ 55.57″	−15.79″	29′ 39.78″	+0.15″	−0.17″
56	9.5	3	3	46 29 58.85	−17.93	29 40.92	+0.17	−0.16
57	12.5	2-3	2-3	46 29 58.75	−19.08	29 39.67	+0.16	−0.16
58	19.4	2-3	2-3	46 30 01.69	−21.82	29 39.87	+0.16	−0.05
59	November 26.4	2-3	2-3	46 30 14.64	−35.10	29 39.54	+0.19	−0.04
60	December 2.3	2	2	46 30 16.54	−36.75	29 39.79	+0.20	−0.03
61	13.3	3	3	46 30 18.93	−39.61	29 39.32	+0.20	+0.00
	1901.							
62	January 20.2	3	3	46 30 23.86	−43.83	29 40.03	+0.23	+0.02
63	30.2	3	3	46 30 22.39	−43.32	29 39.07	+0.22	+0.36
64	February 7.2	2-3	2-3	46 30 21.96	−42.57	29 39.39	+0.22	−0.17

OBSERVATIONS OF POLARIS. CLAMP WEST. S. P.

No.	Date.	I.	S.	App. Z. S. P.	Red. 1900.0.	1900.0. Z.	Run.	Per. error.
	1899.							
1	June 12.3	2	2	48° 57′ 09.77″	−22.14″	56′ 47.63″	−0.01″	−0.00″
2	16.3	2-3	2-3	48 57 10.06	−22.56	56 47.50	−0.02	+0.02
3	23.3	2-3	2	48 57 09.70	−22.89	56 46.81	−0.03	+0.01
4	October 11.9	3	3	48 56 44.75	+01.96	56 46.71	−0.06	+0.08
5	17.9	3-4	3-4	48 56 41.68	+04.20	56 45.88	−0.09	+0.08
6	20.9	2-3	2-3	48 56 40.92	+05.28	56 46.20	−0.07	+0.00
7	23.9	3	3	48 56 40.59	+06.48	56 47.07	−0.09	+0.16
8	24.9	3	3	48 56 39.93	+06.89	56 46.82	−0.09	+0.16
9	November 29.8	3	3	48 56 27.36	+19.05	56 46.41	−0.11	+0.13
10	December 5.8	2	2	48 56 25.17	+20.83	56 46.00	−0.11	+0.11
11	7.8	.....	.....	48 56 24.82	+21.38	56 46.20	−0.12	+0.05
12	19.8	3-2	3-2	48 56 21.82	+24.03	56 45.85	−0.12	−0.02
13	20.8	3	3	48 56 21.64	+24.22	56 45.86	−0.14	+0.00
	1900.							
14	January 21.7	3	3	48 56 19.74	+26.75	56 46.49	−0.17	+0.03
15	22.7	3-4	3	48 56 20.14	+26.69	56 46.83	−0.14	+0.03
16	27.7	3	3	48 56 19.36	+26.52	56 45.88	−0.13	+0.03
17	28.7	3-4	3-4	48 56 19.35	+26.49	56 45.84	−0.15	+0.02
18	30.7	3-4	3-4	48 56 19.56	+26.40	56 45.96	−0.18	+0.06
19	February 9.6	.....	.....	48 56 20.67	+25.23	56 45.90	−0.16	+0.04
20	10.6	3	3	48 56 22.09	+25.12	56 47.21	−0.14	+0.06
21	13.6	4	4	48 56 21.79	+24.71	56 46.50	−0.15	+0.04
22	17.6	3-4	3-4	48 56 22.99	+23.89	56 46.88	−0.15	−0.11
23	March 1.6	4	4	48 56 24.94	+21.40	56 46.34	−0.14	+0.06
24	2.6	.....	.....	48 56 25.66	+21.13	56 46.79	−0.13	+0.06
25	19.6	3	2-3	48 56 30.39	+16.33	56 46.72	−0.10	+0.13
26	23.5	2-3	2-3	48 56 31.74	+15.20	56 46.94	−0.10	+0.04
27	30.5	.....	.....	48 56 33.24	+13.05	56 46.29	−0.11	+0.12
28	31.5	3	3	48 56 33.76	+12.70	56 46.46	−0.10	+0.12
29	April 3.5	3	3	48 56 35.19	+11.74	56 46.93	−0.10	+0.05
30	9.5	3	3-4	48 56 36.08	+09.98	56 47.06	−0.14	+0.02
31	10.5	4	4	48 56 36.52	+09.66	56 47.18	−0.10	+0.04
32	25.4	2-3	2-3	48 56 40.96	+05.05	56 46.01	−0.10	+0.12
33	27.4	.....	.....	48 46 42.45	+04.41	56 46.86	−0.08	+0.09
34	30.4	.....	.....	48 56 42.95	+03.52	56 46.47	−0.10	+0.16

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OBSERVATIONS OF POLARIS. CLAMP WEST. S. P.

No.	Date.	I.	S.	App. Z. S. P.	Red. 1900.0.	1900.0. Z.	Run.	Per. error.
	1900.							
35	May 6.4	2-3	2-3	48° 56′ 44.29″	+02.04″	56′ 46.33″	−0.07″	+0.15″
36	26.3	2-3	2	48 56 49.08	−02.54	56 46.54	−0.06	+0.07
37	June 12.3	2-3	2-3	48 56 51.82	−04.89	56 46.93	−0.10	−0.01
38	18.3	2-3	2-3	48 56 52.52	−05.22	56 47.30	−0.08	−0.09
39	28.3	.....	.....	48 56 52.14	−05.57	56 46.57	−0.06	−0.16
40	July 4.2	2-3	2-3	48 56 52.59	−05.59	56 47.00	−0 05	−0.21
41	5.2	2-3	2-3	48 56 53.28	−05.60	56 47.68	−0.03	−0.21
42	9.2	2	2	48 56 52.21	−05.45	56 46.76	−0.03	−0.20
43	13.2	.....	.....	48 56 52.52	−05.06	56 47.46	−0.05	−0.00
44	21.2	3	2-3	48 56 51.24	−04.41	56 46.83	−0.06	−0.17
45	28.2	2	2	48 56 51.26	−03.30	56 47.96	−0.04	−0.25
46	August 7.2	.....	.....	48 56 48.89	−01.66	56 47.23	−0.03	−0.05
47	10.2	3	3	48 56 47.98	−00.96	56 47.02	−0.06	−0.04
48	24.1	3	3	48 56 44.89	+02.48	56 47.37	−0.05	−0.18
49	29.1	.....	.....	48 56 43.88	+03.72	56 47.60	−0 06	−0.31
50	September 6.1	3	3	48 56 41.44	+06.26	46 47.70	−0.09	−0.06
51	12.1	3	3	48 56 38.03	+08.09	56 46.12	−0.07	−0.06
52	14.1	2-3	2-3	48 56 38.34	+08.75	56 47.09	−0.07	−0.14
53	30.0	3	3	48 56 32.69	+14.40	56 47.09	−0.09	−0.15
54	October 14.0	3	3	48 56 27.99	+19.69	56 47.68	−0.10	−0.24
55	16.9	3-4	3-4	48 56 25.53	+20.90	56 46.43	−0.12	−0.16
56	27.9	2-3	2-3	48 56 21.63	+24.92	56 46.55	−0.12	−0 13
57	30.9	2-3	2-3	48 56 21.50	+26.10	56 47.60	−0.13	−0.08
58	November 3.9	2-3	2 3	48 56 19.25	+27.52	56 46.77	−0.14	−0.12
59	December 1.8	2-3	2-3	48 56 10.03	+36.63	56 46.66	−0.15	−0.23
60	2.8	2	2	48 56 10.59	+36.88	56 47.47	−0.16	−0.23
61	21.8	2-3	2-3	48 56 05.82	+41.25	56 47.07	−0.18	−0.17
	1901.							
62	February 10.6	3	3	48 56 03.89	+41.99	56 45.88	−0.20	−0.22
63	14.6	3-4	2	48 56 05.26	+41.44	56 46.70	−0.19	−0.22

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OBSERVATIONS OF POLARIS. CLAMP WEST. R.

No.	Date.	I.	S.	App, Z. R.	Red. 1900.0.	1900.0. Z.	Run.	Per. error.
	1899.							
1	June 18.8.....	2-3	2-3	133° 30′ 44.78″	−22.79″	30′ 21.99″	−0.06″	+0.00″
2	20.8.....	3	2-3	133 30 45.26	−23.89	30 23.37	−0.02	+0.12
3	24.8.....	3	3	133 30 45.57	−22.88	30 22.69	−0.09	+0.05
4	October 12.5.....	2	2	133 30 19.62	+02.18	30 21.80	−0.14	+0.07
5	15.5.....	3-4	3-4	133 30 18.45	+03.32	30 21.77	−0.07	+0.05
6	31.4.....	2-3	2-3	133 30 13.16	+09.24	30 22.46	−0.16	+0.05
7	December 1.3.....	3	2-3	133 30 08.18	+19.47	30 22.65	−0.19	+0.06
8	4.3.....	2	2	133 30 01.85	+20.39	30 22.24	−0.14	+0.04
9	21.3.....	2-3	3	133 29 57.82	+24.31	30 22.13	−0.19	+0.06
	1900.							
10	June 22.8.....	2	2	133 30 27.82	−05.56	30 22.26	−0.10	−0.13
11	25.8.....	2-3	2-3	133 30 27.19	−05.62	30 21.57	−0.12	−0.12
12	27.8.....	2	2	133 30 27.56	−05.58	30 21.98	−0.09	−0.16
13	July 22.7.....	3	3	133 30 26.75	−04.20	30 22.55	−0.13	−0.12
14	August 25.6.....	4	4	133 30 19.78	+02.87	30 22.65	−0.14	−0.10
15	27.6.....	2-3	2-3	133 30 19.63	+03.34	30 22.97	−0.13	−0.14
16	30.6.....	2-3	2-3	133 30 19.12	+04.13	30 23.25	−0.13	−0.12
17	September 3.6.....	3	3	133 30 18.28	+05.41	30 23.69	−0.13	−0.00
18	25.5.....	3	2	133 30 09.38	+12.75	30 22.13	−0.15	−0.15
19	October 5.5.....	3	3	133 30 07.16	+16.54	30 23.70	−0.17	−0.17
20	14.5.....	3	3	133 30 03.09	+19.89	30 22.98	−0.18	−0.18
21	17.5.....	3	2-3	133 30 01.63	+21.09	30 22.72	−0.16	−0.16
22	20.4.....	2-3	2-3	133 30 00.73	+22.16	30 22.89	−0.15	−0.15
23	December 10.3.....	2	2	133 29 42.27	+38.95	30 21.22	−0.22	−0.12
24	15.3.....	2-3	2 3	133 29 41.61	+39.97	30 21.58	−0.20	−0.06
	1901.							
25	January 22.2.....	3	3	133 29 38.46	+43.81	30 22.27	−0.23	−0.09
26	February 10.1.....	2	2	133 29 41.06	+42.06	30 23.12	−0.20	−0.21

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OBSERVATIONS OF POLARIS. CLAMP WEST. S. P. R.

No.	Date.	I.	S.	App. Z. S. P. R.	Red. 1900.0.	1900.0. Z.	Run.	Per. error.
	1899.							
1	June 11.3	3	3	131° 02′ 53.24″	+22.06″	03′ 15.30″	+0.03″	+0.04″
2	13.3	.....	.....	131 02 52.64	+22.24	03 14.88	+0.05	+0.07
3	17.3	2	2	131 02 52.51	+22.67	03 15.18	+0.00	+0.06
4	December 21.8	2-3	2-3	131 03 39.54	−24.40	03 15.14	+0.15	+0.03
	1900.							
5	February 2.6	2-3	2	131 03 41.20	−26.11	03 15.09	+0.13	+0.01
6	15.6	3	3	131 03 39.91	−24.33	03 15.58	+0.14	+0.00
7	25.6	3	3	131 03 38.83	−22.32	03 16.61	+0.14	+0.03
8	March 11.6	2-3	2-3	131 03 34.90	−18.81	03 16.09	+0.13	+0.02
9	26 5	2	2	131 03 30.15	−14.36	03 15.79	+0.11	+0.04
10	April 4.5	.....	.....	131 03 26.83	−11.44	03 15.39	+0.12	+0.07
11	9.5	3	3-4	131 03 25.16	−09.98	03 15.18	+0.09	+0.12
12	14.5	.....	.....	131 03 23.16	−08.26	03 14.90	+0.08	+0.06
13	22.4	2-3	2-3	131 03 21.88	−05.95	03 15.93	+0.08	+0.02
14	May 4.4	2-3	2-3	131 03 19.05	−02.55	03 16.50	+0.08	+0.07
15	30.3	2	1-2	131 03 11.48	+03.15	03 14.63	+0.07	−0.05
16	June 3.3	2-3	2-3	131 03 11 99	+03.68	03 15.67	+0.08	+0.00
17	12.3	2-3	2-3	131 03 10.28	+04.89	03 15.17	+0.05	+0.01
18	17.3	2-3	2-3	131 03 10.37	+05.15	03 15.52	+0.07	−0.15
19	18.3	2-3	2-3	131 03 10.33	+05.22	03 15.55	+0.04	−0.09
20	19.3	2	2	131 03 09.96	+05.31	03 15.27	+0.07	−0.15
21	25.3	2	2	131 03 08.80	+05.62	03 14.42	+0.05	−0.14
22	July 18.3	2-3	2-3	131 03 10.27	+04 69	03 14.96	+0.06	−0.16
23	25.2	2	2 3	131 03 11.11	+03 78	03 14.89	+0.06	−0.16
24	26.2	.....	.....	131 03 11.46	+03.61	03 15.07	+0.04	+0.04
25	December 11.8	2-3	2 3	131 03 55.69	−39.30	03 16.39	+0.17	−0.03
26	15.8	2-3	2-3	131 03 56.00	−40.06	03 15.94	+0.18	+0.03
	1901.							
27	January 3 .7	3	3	131 03 59.59	−43 31	03 16.28	+0.19	+0.21
28	February 7.6	3	3	131 03 59.42	−42.48	03 16.94	+0.19	−0.22

18. Observation Equations.

For the observations as given in the preceding section observation equations can be wrriten of the form

$$v = \delta_0 - \delta' + \Delta\delta + \Delta k \cdot b \sin(\odot + B) + \pi\, b \cos(\odot + B).$$

δ' is the observed declination, computed from the zenith distance with the latitude + 42° 16′ 48.0″.

δ_0 is the declination of the Berliner Jahrbuch.

Δk is the correction to the aberration constant, 20.445 ″, and π is the parallax. The auxiliary quantities b and B are formed as follows:

$$b \sin B = \sin \alpha \sin \delta \cos \zeta - \cos \delta \sin \zeta.$$

$$b \cos B = -\cos \alpha \sin \delta.$$

With the term $\Delta\delta$ would be included all constant corrections.

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OBSERVATION EQUATIONS. POLARIS, CLAMP EAST.

	Δδ.	b. sin (⊙+B).	b. cos(⊙+B).	n'.	v.
1	+1	−0.306	−0.939	+0 36″	+0.039″
2	1	−0.321	−0.934	+0.29	−0.033
3	1	−0.459	−0.874	+0.57	+0.229
4	1	−0.502	−0.850	+0.81	+0.465
5	1	−0.611	−0.775	+0.72	+0.369
6	1	−0.710	−0.686	+0.49	+0.138
7	1	−0.721	−0.674	+0.36	+0 008
8	1	−0.731	−0.662	+0 18	−0.170
9	1	−0.774	−0.613	+0.83	+0.482
10	+1	−0.803	−0.572	+0.09	−0.254
11	+1	−0.841	−0.517	−0.10	−0.439
12	1	−0.914	−0.372	−0.33	−0.650
13	1	−0.932	−0.326	+0.67	+0.358
14	1	−0.937	−0.310	+1.21	+0.901
15	1	−0.947	−0.278	+0.26	−0.043
16	1	−0.984	−0.069	−0.10	−0.359
17	1	−0.986	−0.037	+0.48	+0.229
18	1	−0.987	+0.012	+1.51	+1.271
19	1	−0.985	+0.061	−0.06	−0.285
20	+1	−0.971	+0.176	−0.19	−0.383
21	+1	−0.968	+0.191	+0.98	+0.792
22	1	−0.965	+0.207	+0.15	−0.034
23	1	−0.953	+0.256	+0.37	+0.202
24	1	−0.949	+0.271	+0.21	+0.046
25	1	−0.897	+0.410	+0.12	+0.004
26	1	−0.860	+0.484	−1.28	−1.368
27	1	−0.827	+0.540	+0.61	+0.544
28	1	−0.768	+0.620	−0.74	−0.771
29	1	−0.702	+0.694	+0.04	+0.044
30	+1	−0.690	+0.706	+0.44	+0.449
31	+1	−0.275	+0.948	−0.08	+0.090
32	1	−0.243	+0.956	−1.15	−0.971
33	1	−0 209	+0 964	−1.15	−0.961
34	1	−0.042	+0.986	+0.75	+0.984
35	1	+0.010	+0.987	−0.83	−0.583
36	1	+0.279	+0.947	−0.32	−0.020
37	1	+0.344	+0.926	+0.14	+0.451
38	1	+0.454	+0.877	−0.73	−0.405
39	1	+0.529	+0.833	−0.44	−0.110
40	+1	+0.543	+0.824	−0.57	−0.238
41	+1	+0.716	+0.679	+0.04	+0.376
42	1	+0.860	+0.484	−0.94	−0.620
43	1	+0.885	+0.437	−0.16	+0.154
44	1	+0.900	+0.406	−1.14	−0.831
45	1	+0.911	+0.382	−0.79	−0.484
46	1	+0.977	+0.137	+0.27	+0.529
47	1	+0.981	+0.105	−0.64	−0.389
48	1	+0.987	−0.018	−0.34	−0.119
49	1	+0.981	−0.106	+0.23	+0.427
50	+1	+0.960	−0.226	−0.43	−0.268
51	+1	+0.947	−0.276	+0.45	+0.595
52	1	+0.906	−0.392	+0.41	+0.517
53	1	+0.842	−0.514	+0.80	+0.860
54	1	+0.793	−0 587	−0.01	+0.020
55	1	+0.761	−0.628	−0.63	−0.619
56	1	+0.666	−0.719	+0.19	+0.156
57	1	+0.600	−0.785	+0.25	+0.183
58	1	+0.064	−0.985	+0.21	−0.035
59	1	+0.020	−0.987	+0.55	+0.294
60	+1	−0.187	−0.969	+0.05	−0.250
61	+1	−0.219	−0.962	+0.15	−0.156
62	1	−0.261	−0.949	−0.04	−0.353
63	1	−0.300	−0.940	+1.13	+0.810
64	1	−0.333	−0.930	−0.56	−0.885
65	1	−0.348	−0.924	−0.14	−0.467

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OBSERVATION EQUATIONS. POLARIS, CLAMP EAST.

	$\Delta\delta$.	b. sin (⊙+B).	b. cos(⊙+B).	n'.	v.
66.	+1	−0.497	−0.852	+0.49	+0.146″
67.	1	−0.526	−0.835	+0.40	+0.053
68.	1	−0.694	−0.702	−0.05	−0.402
69.	1	−0.706	−0.690	+0.12	−0.172
70.	+1	−0.791	−0.591	−0.08	−0.376
71.	+1	−0.810	−0.565	+0.14	−0.205
72.	1	−0.819	−0.551	−0.52	−0.863
73.	1	−0.971	−0.173	+0.29	+0.008
74.	1	−0.987	−0.026	+0.68	+0.431
75.	1	−0.987	+0.007	+0.05	−0.190
76.	1	−0.979	+0.137	−0.02	−0.225
77.	1	−0.966	+0.202	−0.48	−0.665
78.	1	−0.855	+0.493	−0.17	−0.255
79.	1	−0.838	+0.521	+0.71	+0.636
80.	+1	−0.830	+0.535	+1.13	+1.062
81.	+1	−0.620	+0.768	+0.18	+0.232
82.	1	−0.482	+0.862	−0.60	−0.501
83.	1	−0.458	+0.877	+0.53	+0.640
84.	1	−0.249	+0.955	+0.46	+0.637
85.	1	+0.183	+0.969	+0.45	+0.647
86.	1	−0.150	+0.975	−0.32	−0.114

$n' = n - 4.00''$ $[vv] = 22.531.$

A–7–R

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OBSERVATION EQUATIONS. POLARIS S. P., CLAMP EAST.

	Δδ.	b. sin (⊙+B).	b. cos(⊙+B).	n'.	v.
1	+1	−0.313	−0.936	+0.22″	−0.333″
2	1	−0.330	−0.930	−0.42	−0.974
3	1	−0.451	−0.877	+0.24	−0.312
4	1	−0.480	−0.863	+0.31	−0.241
5	1	−0.509	−0.845	−0.14	−0.689
6	1	−0.692	−0.704	+1.29	+0.265
7	1	−0.716	−0.680	+0.46	−0.061
8	1	−0.770	−0.618	+0.38	−0.127
9	1	−0.790	−0.592	+0.19	−0.311
10	+1	−0.808	−0.566	+0.91	+0.416
11	+1	−0.899	−0.409	+0.00	−0.498
12	1	−0.918	−0.364	+0.63	+0.139
13	1	−0.940	−0.308	+0.47	+0.047
14	1	−0.945	−0.286	+1.23	+0.812
15	1	−0.995	−0.061	+0.54	+0.198
16	1	−0.997	−0.012	−0.12	−0.459
17	1	−0.997	+0.021	+0.57	+0.251
18	1	−0.996	+0.037	+0.87	+0.597
19	1	−0.994	+0.070	−0.08	−0.338
20	+1	−0.970	+0.183	+0.28	+0.018
21	+1	−0.967	+0.199	+0.20	−0.036
22	1	−0.937	+0.311	−0.34	−0.553
23	1	−0.914	+0.372	−0.07	−0.260
24	1	−0.901	+0.408	−0.11	−0.256
25	1	−0.856	+0.491	−0.25	−0.392
26	1	−0.708	+0.688	−0.37	−0.425
27	1	−0.696	+0.700	−0.02	−0.069
28	1	−0.684	+0.712	+0.03	−0.013
29	1	−0.267	+0.950	+0.56	+0.654
30	+1	−0.234	+0.958	−0.07	+0.091
31	+1	−0.201	+0.966	−0.08	+0.078
32	1	−0.034	+0.986	−0.61	−0.473
33	1	+0.066	+0.985	−0.26	−0.169
34	1	+0.237	+0.958	+0.81	+0.975
35	1	+0.270	+0.949	−1.07	−0.904
36	1	+0.384	+0.909	+0.65	+0.818
37	1	+0.578	+0.799	+0.18	+0.337
38	1	+0.698	+0.698	−0.24	−0.102
39	1	+0.881	+0.445	−0.94	−0.863
40	+1	+0.899	+0.429	+0.47	+0.543
41	+1	+0.904	+0.398	+0.95	+1.014
42	1	+0.970	+0.181	+1.18	+1.180
43	1	+0.987	+0.026	−1.14	−1.191
44	1	+0.987	−0.027	+0.09	+0.031
45	1	+0.980	−0.114	+0.51	+0.410
46	1	+0.934	−0.319	−0.47	−0.645
47	1	+0.902	−0.400	+0.28	+0.073
48	1	+0.855	−0.492	−0.74	−0.985
49	1	+0.788	−0.594	+0.23	−0.059
50	+1	+0.661	−0.733	+0.44	+0.087
51	+1	+0.621	−0.768	+0.92	+0.550
52	1	+0.257	−0.952	+0.10	−0.332
53	1	−0.012	−0.987	+0.61	+0.079
54	1	−0.028	−0.986	+0.92	+0.388
55	1	−0.044	−0.986	+0.36	−0.174
56	1	−0.213	−0.964	+1.02	+0.470
57	1	−0.244	−0.956	−0.02	−0.571
58	1	−0.292	−0.943	+0.64	+0.087
59	1	−0.417	−0.894	+1.19	+0.637
60	+1	−0.447	−0.880	+0.50	−0.052
61	+1	−0.490	−0.857	+0.20	−0.350
62	1	−0.700	−0.696	+0.87	+0.346
63	1	−0.744	−0.648	+0.83	+0.317
64	1	−0.795	−0.584	+1.71	+1.211
65	1	−0.985	−0.067	+0.72	+0.371

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OBSERVATION EQUATIONS. POLARIS S. P., CLAMP EAST.

	$\Delta\delta$.	b. sin (⊙+B).	b. cos(⊙+B).	n'.	v.
66	1	−0.987	+0.015	+1.04″	+0.719″
67	1	−0.987	+0.031	+1.14	+0.825
68	1	−0.988	+0.194	−0.04	−0.298
69	1	−0.916	+0.367	−0.36	−0.552
70	+1	−0.882	+0.442	−0.05	−0.212
71	+1	−0.842	+0.513	−0.06	−0.193
72	1	−0.800	+0.783	−0.28	−0.388
73	1	−0.567	+0.793	−0.49	−0.492
74	1	−0.518	+0.840	−0.10	−0.077
75	1	−0.489	+0.858	−0.24	−0.207
76	1	−0.460	+0.873	−0.32	−0.778
77	+1	−0.414	+0.896	+0.78	+0.835

n' = n +4.00″ [vv] = 21.565.

OBSERVATION EQUATIONS. POLARIS R., CLAMP EAST.

	$\Delta\delta$.	b. sin (⊙+B).	b. cos(⊙+B).	n'.	v.
1	+1	−0.917	+0.364	+0.36″	+0.329″
3	1	−0.827	+0.540	−0.34	−0.453
2	1	−0.757	+0.633	−0.40	−0.550
4	1	+0.077	+0.984	+0.76	+0.617
5	1	+0.376	+0.913	−0.11	−0.133
6	1	+0.391	+0.906	−0.16	−0.176
7	1	+0.627	+0.763	+0.86	+0.989
8	1	+0.728	+0.666	−0.29	−0.077
9	1	+0.924	+0.357	−0.88	−0.433
10	+1	+0.953	+0.261	−0.34	+0.170
11	+1	+0.965	+0.206	−0.76	−0.214
12	1	+0.979	+0.121	−1.40	−0.800
13	1	+0.987	+0.018	−0.25	+0.413
14	1	+0.987	−0.036	−0.72	−0.025
15	1	+0.968	−0.192	−1.11	−0.327
16	1	+0.919	−0.359	−0.39	+0.479
17	1	−0.979	+0.129	+0.50	+0.592
18	1	−0.969	+0.187	−0.26	−0.200
19	1	−0.925	+0.343	+0.91	+0.869
20	+1	−0.919	+0.359	−0.23	−0.259
21	+1	−0.892	+0.419	−0.51	−0.567
22	1	−0.885	+0.434	+0.24	+0.176
23	1	−0.607	+0.774	−0.86	−1.067
24	1	−0.468	+0.870	+0.94	+0.725
25	+1	−0.438	+0.885	+0.10	−0.117

n' = n −1.00″ [vv] = 6.701.

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OBSERVATION EQUATIONS. POLARIS S. P. R. CLAMP EAST.

	$\Delta\delta$.	b. sin (⊙+B).	b. cos(⊙+B).	n′.	v.
1.	+1	−0.565	−0.809	+0.62″	+0.635″
2.	1	−0.618	−0.770	−0.20	−0.199
3.	1	+0.967	+0.197	−0.13	−0.388
4.	1	+0.978	+0.128	+0.13	−0.107
5.	1	+0.982	+0.095	+0.55	+0.324
6.	1	+0.978	−0.131	+0.21	+0.054
7.	1	+0.973	−0.184	−0.09	−0.230
8.	1	+0.956	−0.235	−0.05	−0.174
9.	1	+0.755	−0.636	+0.90	+0.894
10.	+1	+0.607	−0.779	−0.27	−0.235
11.	+1	+0.073	−0.984	+0.30	+0.385
12.	1	+0.055	−0.996	+0.18	+0.265
13.	1	−0.096	−0.982	−0.13	−0.050
14.	1	−0.112	−0.980	−0.73	−0.651
15.	1	−0.162	−0.974	−0.45	−0.374
16.	1	−0.308	−0.988	−0.27	−0.209
17.	1	−0.340	−0.927	+0.12	+0.176
18.	1	−0.490	−0.857	+0.10	+0.132
19.	1	−0.744	−0.648	−0.68	−0.720
20.	+1	−0.958	−0.236	+0.06	−0.114
21.	+1	−0.964	−0.293	+0.32	+0.164
22.	1	−0.970	−0.181	−0.31	−0.501
23.	1	−0.973	−0.165	+0.20	+0.004
24.	+1	−0.976	−0.148	+1.11	+0.909

$[vv] = 4.161.$

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OBSERVATION EQUATIONS. POLARIS, CLAMP WEST.

	$\Delta\delta$.	b. sin (⊙+B).	b. cos(⊙+B).	n′.	v.
1.	+1	−0.871	−0.466	−0.38″	−0.524″
2.	1	−0.906	−0.392	+0.46	+0.300
3.	1	−0.913	−0.377	−0.11	−0.273
4.	1	−0.099	+0.982	+0.28	+0.057
5.	1	−0.031	+0.987	+0.15	−0.063
6.	1	+0.189	+0.969	−0.19	−0.367
7.	1	+0.205	+0.965	+0.02	−0.154
8.	1	+0.712	+0.684	+0.26	+0.201
9.	1	+0.911	+0.379	+0.06	+0.072
10.	+1	+0.925	+0.347	+1.03	+1.049
11.	+1	+0.959	+0.229	+1.02	+1.060
12.	1	+0.962	−0.220	−0.13	−0.029
13.	1	+0.958	−0.237	+0.08	+0.133
14.	1	+0.949	−0.271	+0.01	+0.116
15.	1	+0.921	−0.353	−0.83	−0.717
16.	1	+0.901	−0.402	−0.24	−0.124
17.	1	+0.836	−0.525	+0.08	+0.153
18.	1	+0.827	−0.540	−0.56	−0.436
19.	1	+0.817	−0.555	−0.72	−0.596
20.	+1	+0.731	−0.662	+0.06	+0.185
21.	+1	+0.591	−0.791	−0.31	−0.188
22.	1	+0.577	−0.800	+0.40	+0.521
23.	1	+0.271	−0.949	+0.67	+0.764
24.	1	+0.254	−0.953	+0.30	+0.398
25.	1	+0.137	−0.977	−0.05	+0.028
26.	1	+0.121	−0.980	+0.04	+0.115
27.	1	+0.070	−0.984	+0.52	+0.589
28.	1	+0.020	−0.987	−0.49	−0.429
29.	1	−0.182	−0.969	+0.26	+0.288
30.	+1	−0.295	−0.943	−0.57	−0.563
31.	+1	−0.342	−0.926	−1.04	−1.042
32.	1	−0.373	−0.914	−0.01	−0.019
33.	1	−0.433	−0.887	+0.15	+0.129
34.	1	−0.653	−0.739	+0.35	+0.274
35.	1	−0.883	−0.442	−0.78	−0.929
36.	1	−0.897	−0.413	−0.38	−0.535
37.	1	−0.904	−0.398	−0.09	−0.248
38.	1	−0.917	−0.367	0.00	−0.164
39.	1	−0.928	−0.337	−0.47	−0.641
40.	+1	−0.987	+0.017	+0.73	+0.503
41.	+1	−0.986	+0.034	+1.02	+0.790
42.	1	−0.983	+0.083	+0.76	+0.525
43.	1	−0.970	+0.181	+0.57	+0.324
44.	1	−0.956	+0.245	+1.48	+1.227
45.	1	−0.909	+0.384	+0.42	+0.155
46.	+1	−0.895	+0.415	−0.18	−0.447
47.	1	−0.888	+0.429	−0.08	−0.348
48.	1	−0.823	+0.544	+0.69	+0.417
49.	1	−0.814	+0.558	+0.51	+0.236
50.	+1	−0.786	+0.598	+0.10	−0.175
51.	+1	−0.637	+0.754	+1.58	+1.306
52.	1	−0.335	+0.927	+0.68	+0.429
53.	1	−0.288	+0.957	+0.74	+0.500
54.	1	−0.204	+0.965	−0.45	−0.686
55.	1	−0.140	+0.977	−0.13	−0.358
56.	1	−0.038	+0.986	−1.30	−1.514
57.	1	+0.014	+0.987	−0.04	−0.246
58.	1	+0.133	+0.978	−0.35	−0.537
59.	1	+0.708	+0.688	−0.06	−0.120
60.	+1	+0.777	+0.609	−0.33	−0.369
61.	+1	+0.879	+0.448	+0.11	+0.109
62.	1	+0.967	−0.197	−0.65	−0.551
63.	1	+0.917	−0.364	−0.02	+0.093
64.	+1	+0.857	−0.490	+0.19	+0.311

n′ = n +1.00″ [vv] = 18.191.

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OBSERVATION EQUATIONS. POLARIS S. P., CLAMP WEST.

	$\Delta\delta$.	b. sin (⊙+B).	b. cos(⊙+B).	n′.	v.
1.	+1	−0.881	−0.444	+1.25″	+0.687″
2.	1	−0.909	−0.384	+1.13	+0.548
3.	1	−0.947	−0.276	+0.42	−0.191
4.	1	+0.011	+0.987	+0.36	+0.012
5.	1	+0.113	+0.980	−0.50	−0.805
6.	1	+0.164	+0.973	−0.24	−0.522
7.	1	+0.214	+0.963	+0.77	+0.510
8.	1	+0.231	+0.959	+0.52	+0.369
9.	1	+0.752	+0.658	+0.06	+0.068
10.	+1	+0.816	+0.555	−0.37	−0.325
11.	+1	+0.836	+0.525	−0.24	−0.183
12.	1	+0.927	+0.339	−0.66	−0.542
13.	1	+0.933	+0.332	−0.65	−0.528
14.	1	+0.960	−0.239	−0.02	+0.178
15.	1	+0.956	−0.246	+0.35	+0.548
16.	1	+0.930	−0.330	−0.59	−0.394
17.	1	+0.924	−0.346	−0.66	−0.464
18.	1	+0.912	−0.378	−0.53	−0.336
19.	1	+0.832	−0.532	−0.59	−0.412
20.	+1	+0.822	−0.547	+0.76	+0.985
21.	+1	+0.792	−0.589	+0.02	+0.187
22.	1	+0.748	−0.644	+0.25	+0.405
23.	1	+0.597	−0.786	−0.11	−0.008
24.	1	+0.584	−0.796	+0.35	+0.452
25.	1	+0.327	−0.931	+0.88	+0.389
26.	1	+0.263	−0.951	+0.51	+0.493
27.	1	+0.146	−0.976	−0.07	−0.134
28.	1	+0.129	−0.979	+0.11	+0.040
29.	1	+0.079	−0.984	+0.51	+0.419
30.	+1	−0.022	−0.987	−0.43	−0.564
31.	+1	−0.039	−0.986	−0.25	−0.392
32.	1	−0.286	−0.945	−0.34	−0.591
33.	1	−0.319	−0.934	+0.50	+0.283
34.	1	−0.363	−0.917	+0.16	−0.128
35.	1	−0.457	−0.875	+0.04	−0.292
36.	1	−0.718	−0.676	+0.18	−0.288
37.	1	−0.879	−0.449	+0.45	−0.112
38.	1	−0.920	−0.360	+0.76	+0.170
39.	1	−0.966	−0.202	−0.02	−0.648
40.	+1	−0.981	−0.105	+0.37	−0.276
41.	+1	−0.983	−0.089	+1.07	+0.421
42.	1	−0.997	−0.024	+0.16	−0.497
43.	1	−0.986	+0.042	+1.04	+0.375
44.	1	−0.972	+0.178	+0.23	−0.444
45.	1	−0.946	+0.284	+1.30	+0.624
46.	1	−0.885	+0.437	+0.78	+0.112
47.	1	−0.862	+0.481	+0.55	−0.113
48.	1	−0.727	+0.668	+0.77	+0.144
49.	1	−0.668	+0.726	+0.86	+0.252
50.	+1	−0.564	+0.809	+1.18	+0.606
51.	+1	−0.480	+0.868	−0.38	−0.924
52.	1	−0.450	+0.878	+0.51	−0.023
53.	1	−0.196	+0.967	+0.48	+0.045
54.	1	+0.040	+0.966	+0.97	+0.534
55.	1	+0.091	+0.962	−0.22	−0.534
56.	1	+0.275	+0.948	−0.07	−0.302
57.	1	+0.325	+0.933	+1.02	+0.812
58.	1	+0.388	+0.908	+0.14	−0.038
59.	1	+0.771	+0.616	−0.09	−0.071
60.	+1	+0.782	+0.602	+0.71	+0.735
61.	+1	+0.937	+0.311	+0.35	+0.475
62.	1	+0.825	−0.542	−0.93	−0.764
63.	+1	+0.786	−0.598	−0.10	+0.066

$n' = n - 1.00''$ $[vv] = 12.510.$

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OBSERVATION EQUATIONS. POLARIS R. CLAMP WEST.

	$\Delta\delta$.	b. sin (⊙+B).	b. cos(⊙+B).	n'.	v.
1.	+1	−0.925	−0.346	−0.44″	−0.252′
2.	1	−0.936	−0.315	+0.03	+0.206
3.	1	−0.958	−0.253	+0.35	+0.501
4.	1	+0.019	+0.987	−0.64	−0.667
5.	1	+0.070	+0.984	−0.62	−0.634
6.	1	+0.328	+0.928	−0.08	−0.012
7.	1	+0.769	+0.618	+0.15	+0.430
8.	1	+0.801	+0.576	−0.23	+0.072
9.	1	+0.936	+0.313	−0.37	+0.053
10.	+1	−0.943	−0.289	−0.34	−0.175
11.	+1	−0.956	−0.242	−1.04	−0.894
12.	1	−0.964	−0.210	−0.64	−0.507
13.	1	−0.967	+0.196	−0.07	−0.074
14.	1	−0.710	+0.686	+0.04	−0.065
15.	1	−0.686	+0.710	+0.33	+0.223
16.	1	−0.649	+0.743	+0.63	+0.521
17.	1	−0.598	+0.786	+1.19	+1.079
18.	1	−0.270	+0.949	−0.54	−0.625
19.	1	−0.107	+0.982	+0.99	+0.934
20.	+1	+0.048	+0.986	+0.25	+0.231
21.	+1	+0.100	+0.981	+0.03	+0.024
22.	1	+0.150	+0.976	+0.22	+0.229
23.	1	+0.854	+0.494	−1.49	−1.147
24.	1	+0.895	+0.416	−1.05	−0.671
25.	1	+0.959	−0.232	−0.42	+0.192
26.	+1	+0.830	−0.535	+0.34	+1.021

$n' = n - 1.00''$ $[vv] = 8.192.$

OBSERVATION EQUATIONS. POLARIS S. P. R. CLAMP WEST.

	$\Delta\delta$.	b. sin (⊙+B).	b. cos(⊙+B).	n'.	v.
1.	+1	−0.874	−0.458	+0.26″	−0.145″
2.	1	−0.888	−0.428	+0.37	−0.051
3.	1	−0.916	−0.368	+0.39	−0.064
4.	1	+0.939	+0.305	+0.81	+0.718
5.	1	+0.889	−0.425	+0.40	+0.979
6.	1	+0.772	−0.617	−0.09	+0.475
7.	1	+0.650	−0.742	−1.05	−0.519
8.	1	+0.453	−0.877	−0.61	−0.154
9.	1	+0.212	−0.963	−0.31	+0.034
10.	+1	+0.062	−0.985	+0.05	+0.316
11.	+1	−0.022	−0.987	+0.24	+0.459
12.	1	−0.106	−0.981	+0.59	+0.760
13.	1	−0.239	−0.957	−0.40	−0.312
14.	1	−0.426	−0.890	−1.12	−1.155
15.	1	−0.761	−0.627	+0.98	+0.685
16.	1	−0.802	−0.575	−0.12	−0.453
17.	1	−0.879	−0.449	+0.40	−0.010
18.	1	−0.913	−0.374	+0.19	−0.260
19.	1	−0.920	−0.360	+0.13	−0.328
20.	+1	−0.925	−0.344	+0.44	−0.025
21.	+1	−0.954	−0.250	+1.30	+0.793
22.	1	−0.979	+0.123	+0.77	+0.147
23.	1	−0.958	+0.237	+0.84	+0.198
24.	1	−0.954	+0.253	+0.48	−0.164
25.	1	+0.868	+0.472	−0.90	−0.578
26.	1	+0.899	+0.409	−0.52	−0.164
27.	1	+0.914	−0.372	−1.06	−0.481
28.	+1	+0.852	−0.497	−1.28	−0.702

$n' = n + 1.00''$ $[vv] = 6.993.$

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Corresponding to the several sets of observations are normal equations and solutions as follows:

Clamp East, above pole.

+86.000 Δδ	−23.895 Δk	− 2.561 π	+ 6.980 = 0
−23.895	+46.133	+ 3.692	−12.073 = 0
− 2.561	+ 3.692	+37.616	−10.536 = 0

			wt.
Δδ	= −4.008″	±0.041″	73.6
Δk	= +0.237	±0.056	39.3
π	= +0.256	±0.058	37.3

[nn. 3] = 22.523 [vv] = 22.521.
Probable error one equation = r = ±0.351″.

Clamp East, below pole.

+77.000 Δδ	−23.069 Δk	− 2.464 π	+18.820 = 0
−23.069	+40.317	+ 1.281	−10.318 = 0
− 2.464	+ 1.281	+34.670	−12.450 = 0

			wt.
Δδ	= +3.807″	±0.046″	63.7
Δk	= +0.135	±0.063	33.4
π	= +0.340	±0.062	34.6

[nn. 3] = 21.558 [vv] = 21.565 r = ±0.364″.

Clamp East, reflected, above pole.

+25.000 Δδ	+ 0.298 Δk	+10.549 π	−4.340 = 0
+ 0.298	+16.658	− 2.144	−5.682 = 0
+10.549	− 2.144	+ 7.701	+0.677 = 0

			wt.
Δδ	= −0.580″	±0.118″	9.9
Δk	= +0.257	±0.096	15.1
π	= −0.592	±0.217	2.9

[nn. 3] = 6.702 [vv] = 6.701 r = ±0.372″.

Clamp East, reflected, below pole.

+24.000 Δδ	−0 .950 Δk	−12.423 π	+1.490 = 0
− 0.950	+13.064	+ 2.587	+0.255 = 0
−12.423	+ 2.587	+10.358	+0.392 = 0

			wt.
Δδ	= −0.222″	±0.102″	8.7
Δk	= +0.026	±0.087	11.9
π	= −0.310	±0.158	3.6

[nn. 3] = 4.150 [vv] = 4.161 r = ±0.300″.

Clamp West, above pole.

+64.000 Δδ	− 2.120 Δk	− 2.499 π	+ 4.790″ = 0
− 2.120	+32.741	− 2.349	− 5.456 = 0
− 2.499	− 2.349	+29.602	+ 4.179 = 0

			wt.
Δδ	= +0.925″	±0.046″	63.6
Δk	= +0.152	±0.065	32.5
π	= −0.135	±0.068	29.3

[nn. 3] = 18.185 [vv] =18.191 r = ±0.368″.

Clamp West, below pole.

+63.000 Δδ	+ 1.825 Δk	− 0.171 π	+14.270″ = 0
+ 1.825	+30.481	− 0.775	−12.686 = 0
− 0.171	− 0.775	+30.891	+ 3.879 = 0

			wt.
Δδ	= −1.239″	±0.039″	62.9
Δk	= +0.427	±0.056	30.4
π	= −0.116	±0.055	30.9

[nn. 3] = 12.493 [vv] = 12.510 r = ±0.308″.

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Clamp West, reflected, above pole.

+26.000 $\Delta\delta$	− 2.905 Δk	+10.889 π	−3.420″ = 0
− 2.905	+13.540	+ 1.125	−2.071 = 0
+10.889	+ 1.125	+11.777	+0.410 = 0

		wt.
$\Delta\delta$ = −0.701″	±0.105″	14.8
Δk = +0.245	±0.114	12.4
π = −0.334	±0.154	6.8

[un. 3] = 8,196 [vv] = 8.192 r = ±0.405.

Clamp West, reflected, below pole.

+28.000$\Delta\delta$	− 5.006 Δk	−11.727 π	+0.680″ = 0
− 5.006	+16.934	+ 2.126	−9.188 = 0
−11.727	+ 2.126	+10.330	+1.178 = 0

		wt.
$\Delta\delta$ = +0.962″	±0.094″	14.3
Δk = +0.563	±0.089	16.0
π = −0.273	±0.153	5.4

nn. 3] = 6.966 [vv] = 6.993 r = ±0.357″.

On looking over the residuals it will be seen that some are large. But it is doubtful whether any could fairly be omitted. It will be observed, also, that there are changes in the signs of the residuals which seem to correspond to sudden changes in the structural condition of the instrument. However, the observations above and below pole ought to eliminate such changes.

In combining the above results, therefore, probably the reflected observations should be omitted. If the mean is taken of the values derived from direct observations we have

$$\Delta k = +0.238'', \text{ or } k = 20.683''.$$

As stated before, in handling the meridian circle hereafter, I hope to be able to make frequent reversals, and improve somewhat the accuracy of the observations. It requires one day's work with an assistant to reverse the instrument and readjust the microscopes. Microscopes of higher magnifying power might be employed, also, for reading the circles, and it is expected to make some improvement in this direction.

19.—Latitude.

To find the latitude from the Polaris observations the mean of the results reduced to 1900.0 can be taken, so that we have

1900.0.

Clamp East.	No. observ's.	Z.	Division under Micr. I.	Div. error.	Red. for runs.	Per. error.
Above pole	86	46° 29′ 34.53″	205° 04-06′	+0.75″	+0.064″	−0.041″
Below pole	77	48 56 41.71	202 36-38	+0.47	−0.051	−0.041
Above pole, reflected	25	133 30 22.35	118 00-02	+0.17	−0.103	−0.053
Below pole, reflected	24	131 03 14.58	120 28-30	+0.17	+0.042	−0.054
Clamp West.						
Above pole	64	46 29 39.46	298 00-02	−0.17	+0.148	−0.048
Below pole	63	48 56 46.76	300 28-30	−0.17	−0.101	−0.030
Above pole, reflected	26	133 30 22.44	25 04-06	−0.75	−0.142	−0.065
Below pole, reflected	28	131 03 15.44	22 36-38	−0.47	+0.094	−0.014

$\Delta\phi$ for position of reflection basin = −0.02″.

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If now the mean is taken of these corrected zenith distances, each being weighted unity, we have for the latitude

$$\phi = +42^\circ\ 16'\ 48.78''.$$

A few observations of δ Ursae Minoris, and 51H Cephei give respectively 48.80″ and 48.96″. They were taken like Polaris, above and below pole, direct and reflected, but no division errors were applied.

I acknowledge gratefully a grant from the Bache Fund of the National Academy of Sciences for assistance in computing.

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